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(71) Applicant: TECHNISCHE UNIVERSITEIT DELFT

[NL/NL]; Stevinweg 1, 2628 CN Delft (NL).

(72) Inventors: LANDERS, John Earl; c/o TU Delft Innovation & Impact Centre, P.O. Box 5, 2600 AA DELFT (NL).

VALLERY, Heike; c/o TU Delft Innovation & Impact Centre, P.O. Box 5, 2600 AA DELFT (NL).

SMIT, Gerhardus; c/o TU Delft Innovation & Impact Centre, P.O. Box 5, 2600 AA DELFT (NL).

(74) Agent: VAN BREDA, Jacques; Weteringschans 96, 1017

XS Amsterdam (NL).

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(54) Title: TRANSFEMORAL KNEE-ANKLE PROSTHESIS

(57) Abstract: A transfemoral knee-ankle prosthesis, comprising a knee portion (14-18), an ankle portion (19-23), an actuator portion (1-3, 9, 10), and a shank portion (24), wherein the shank rigidly connects the knee portion with the ankle portion, and the actuator portion (1-3, 9, 10) is biarticular and connects the knee portion (14-18) to the ankle portion (19-23) without an intermediate connection to the shank (24). The actuator portion (1-3, 9, 10) comprises a bidirectional pneumatic cylinder (1) and a hydraulic locking cylinder (9), which are rigidly coupled to each other with cylinder end caps (12) provided on opposite sides of the pneumatic cylinder (1) and the hydraulic cylinder (9).



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Transfemoral knee-ankle prosthesis

The invention relates to a transfemoral knee-ankle prosthesis, comprising a knee portion, an ankle portion, an actuator portion, and a shank portion, wherein the shank rigidly connects the knee portion with the ankle portion.

US2015182354A1 pertains to a femoral knee-ankle prosthesis intended for persons who are lower-limb amputees but still have a segment suitable for a femoral connection and a tibial connection connected to the femoral segment based on an articulation which reproduces the movements of the knee, the said tibial segment being articulated on one foot based on an articulation reproducing the movements of the ankle, an initial damper the ends of which are joined respectively with the femoral and tibial segments, and another hydraulic damper of which the ends are joined respectively with the tibial and foot segment. The chamber of the first hydraulic damper is connected to the chamber of the second hydraulic damper and it comprises means of controlling the first and/or second hydraulic damper depending on the phase of the walking cycle such as the stance phase or the swing phase and/or real-life situations such as stairs, slopes or standing, etc., in such a manner that the flexion of the knee allows the dorsiflexion of the ankle in proportion to the movement of the knee during the stance phase and such that the flexion of the knee results in the dorsiflexion of the ankle during the swing phase.

US2010/0241242, WO2012/177125, US2018/0133031, and US2016/0228265 each disclose a transfemoral knee-ankle prosthesis, comprising a knee portion, an ankle portion, an actuator portion, and a shank portion, wherein the shank rigidly connects the knee portion with the ankle portion, and the actuator portion is biarticular and connects the knee portion to the ankle portion without an intermediate connection to the shank.

There are several problems with the known knee-ankle prosthesis, to note it is complicated and therefore costly, and it does particularly not optimally mimic a person's natural leg movements.

It is an object of the invention to address these problems of the prior art.

To this end the knee-ankle prosthesis of the invention has the features of one or more of the appended claims.

5 According to a first aspect of the invention besides that the actuator portion is biarticular and connects the knee portion to the ankle portion without an intermediate connection to the shank, the actuator portion comprises a bidirectional pneumatic cylinder and a hydraulic locking cylinder, which are
10 rigidly coupled to each other with cylinder end caps provided on opposite sides of the pneumatic cylinder and the hydraulic cylinder, wherein the hydraulic locking cylinder is provided with an hydraulic locking valve in order to arrest the hydraulic locking cylinder when required, such that during gait, opening
15 and closing of the hydraulic locking valve is dependent on a measured angle of the knee portion with reference to the shank.

This configuration allows the actuator portion to have a variable gearing about both joints (knee portion and ankle portion), such that a change in angle at either the knee or the
20 ankle joint can cause the moment arms of the actuator about both the knee and the ankle to change by adjusting the actuator's line of action. This is significant to the operation of the device because it makes the moment generated by the actuator around each joint no longer a function of the joint's angle
25 alone, even when a fixed force-length relation of the actuator is assumed, as is the case for most passive elements.

The piston-cylinder geometry contributes to the biomimetic matching of the joint moment profiles produced by a healthy leg during movement by determining the force-length
30 relation of the actuator portion. For this functionality, it is as mentioned above important that the actuator portion is not rigidly attached to the shank, because the lack of this connection allows the line of action of the cylinder at the ankle portion to be adjusted by the angle of the knee portion,
35 therefore making the moment arm at the ankle portion a function of both knee and ankle angle. This is preferable because the moment arm profile at the ankle portion required to produce biomimetic joint profiles is not a function of ankle angle alone.

Preferably the pneumatic cylinder comprises a pneumatic piston rod, and the hydraulic locking cylinder comprises an hydraulic piston rod, and that the pneumatic piston rod and the hydraulic piston rod are rigidly coupled to each other with a coupling so that the two cylinders have directly proportional length changes. This way, when the flow between the two sides of the hydraulic cylinder is cut-off, the pneumatic cylinder is also locked and can passively store energy in the form of compressed air as will be further explained hereinafter.

When the hydraulic cylinder is locked it also creates a rigid coupling between the knee portion and the ankle portion, putting a constraint on the knee and ankle motion. In some tasks this is desirable, but in others it is desirable for the knee and ankle to have unconstrained motion when the actuator portion is locked. To accommodate for this, it is preferable that between the actuator portion and the knee portion a releasable connector is provided.

In a suitable embodiment the releasable connector is connectable to the pneumatic piston rod with a controllable lock pin. This can be suitably arranged in that the controllable lock pin is movable in or out of aligned holes in the releasable connector and the pneumatic piston rod. There are many ways in which this can be achieved, for instance the controllable lock pin can be one selected from a spring-loaded button and a toggling pin device.

In a further aspect of the invention the knee portion is polycentric pivotable with reference to the shank. This supports and promotes the exact mimicking of the natural leg movements of a person wearing the knee-ankle prosthesis of the invention. This can be further promoted when also the ankle portion is polycentric pivotable with reference to the shank.

In an especially suitable embodiment of the knee-ankle prosthesis of the invention providing the above-mentioned polycentric pivoting of the knee and/or ankle, at least one of the knee portion and the ankle portion comprises a four bar linkage connecting a lower segment and an upper segment of the knee portion and ankle portion, respectively.

Most preferably each of the knee portion and the ankle portion comprises a four bar linkage, wherein a lower segment

of the knee portion and an upper segment of the ankle portion are connected to each other through the shank.

It is preferable that a cylinder rod of the pneumatic hydraulic cylinder connects with a forked bracket anterior to the shank to opposite sides of the ankle portion. This enables the pneumatic cylinder to stay in line with and posterior to the shank during motion of the prosthesis.

To avoid collision of the respective parts of the knee-ankle prosthesis near the ankle portion, it is preferable that the forked bracket is connected to an attachment point that is exterior of the linkages of the four bar linkage connecting the upper segment and the lower segment of the ankle portion.

To assist the gait functionality of the prosthesis, the pneumatic cylinder is connected to a first check valve enabling air to flow from a distal compartment to a proximal compartment separated by a piston from the distal compartment, wherein the distal compartment is more distant from the knee portion than the proximal compartment.

Desirably the pneumatic cylinder is provided with a pressure release valve which serves to vent air from the proximal compartment to the distal compartment if a pressure in the proximal compartment exceeds a predetermined value.

To assist a sitting and standing functionality of the prosthesis, the pneumatic cylinder is connected to a second check valve enabling air to flow from a proximal compartment to a distal compartment separated by a piston from the proximal compartment, wherein the distal compartment is more distant from the knee portion than the proximal compartment.

In order to limit the amount of components of the knee-ankle prosthesis of the invention it is preferred that the first check valve and the second check valve form part of a single 2/2 spool valve.

During sitting it is preferred that the hydraulic locking valve is closed.

The said closing of the hydraulic locking valve during sitting is preferably depending on a measured angle of the knee portion with reference to the shank.

The invention will hereinafter be further elucidated with reference to the drawing of an exemplary embodiment of a

knee-ankle prosthesis according to the invention that is not limiting as to the appended claims.

In the drawing:

- figure 1 shows a knee ankle prosthesis of the invention in an isometric view;
- figure 2 shows a detail A of the prosthesis of the invention;
- figure 3 shows a detail B of the prosthesis of the invention;
- figure 4 shows a detail C of the prosthesis of the invention;
- figure 5 shows a gait motion with the prosthesis of the invention;
- figures 6-10 shows isolated frames taken from the moments depicted in figure 5;
- figure 11 shows stand-to-sit and sit-to-stand motions with the prosthesis of the invention;
- figures 12-17 shows isolated frames taken from the moments depicted in figure 11.

Whenever in the figures the same reference numerals are applied, these numerals refer to the same parts.

One possible configuration of the prosthesis of the invention is shown in the figures and will be further explained hereinafter. This description is one of many possible embodiments for the prosthesis of the invention and is in no way limiting to the claims appended hereto.

The transfemoral knee-ankle prosthesis of the invention as shown in figure 1 comprises four major portions: a knee portion 14-18, an ankle portion 19-23, an actuator portion 1-3 and 9, 10, and a shank portion 24.

The prosthesis is configured such that the shank 24 rigidly connects a lower section 15 of the knee portion 14-18 with an upper segment 19 of the ankle portion 19-23 and provides the primary structural support of the leg. The actuator portion 1-3 and 9, 10 is biarticular and connects an upper segment 14 of the knee portion to a lower segment 20 of the ankle portion without any intermediate connection to the shank 24. This configuration allows the actuator portion 1-3 and 9, 10, to have a variable gearing about both joints, such that a change in

angle at either the knee portion 14-18 joint or the ankle portion 19-23 joint can cause the moment arms of the actuator portion about both the knee and the ankle to change by adjusting the actuator's line of action. This is significant to the operation of the prosthesis of the invention because it makes the moment generated by the actuator portion around each joint no longer a function of the joint's angles alone, even when a fixed force-length relation of the actuator portion is assumed, as is the case for most passive elements.

In the shown embodiment the actuator portion 1-3 and 9, 10 comprises a bidirectional pneumatic cylinder 1 rigidly coupled to a hydraulic locking cylinder 9 via cylinder end caps 12. The pneumatic piston rod 2 and hydraulic piston rod 10 are also rigidly connected by a coupling 11 so that the two cylinders have directly proportional length changes. This way, when the flow between the two compartments on opposite sides of a piston in the hydraulic cylinder 9 is cut-off, for instance by a preferably single 2/2 hydraulic valve 13, the pneumatic cylinder 1 is also locked and can passively store energy in the form of compressed air.

Preferably the knee portion 14-18 is polycentric pivotable with reference to the shank 24. This can be accomplished by a four bar linkage embodied by the combination of an upper knee segment 14, a lower knee segment 15, links 16 and 17 and joints 18.

Preferably also the ankle portion 19-23 is polycentric pivotable with reference to the shank 24. This can be accomplished by another four bar linkage embodied by the combination of an upper ankle segment 19, a lower ankle segment 20, links 21 and 22 and joints 23.

In the shown embodiment the upper segment 14 of the knee and the lower segment 20 of the ankle are connected via the actuator portion 1-3 and 9, 10, whereas the lower segment of the knee 15 and the upper segment of the ankle 19 are connected via the shank 24..

The polycentric knee and ankle joint in this embodiment have both the above-mentioned four bar linkages, but in principle any polycentric joint could be used.

Figure 1 depicts further that both at the top of the polycentric knee and at the bottom of the polycentric ankle there is a standard prosthetic pyramidal attachment nub 25, allowing the prosthesis to be used with any commercial foot and socket. It is recommended however, that the prosthesis of the invention be used with a low-profile foot, either of the ESR or SACH foot variety.

When the hydraulic cylinder 9 is locked it also creates a rigid coupling between the upper segment 14 of the polycentric knee and the lower segment 20 of the polycentric ankle, putting a constraint on the knee and ankle motion. In some tasks this is desirable, but in others it is desirable for the knee and ankle to have unconstrained motion when the actuator portion 1-3 and 9, 10 is locked. To accommodate for this, an end cap connector 6 is placed in series between the pneumatic piston rod 2 and the proximal actuator attachment point 4 to the knee portion 14-18.

As shown in figure 3-Detail B and figure 4-Detail C, the top end of the pneumatic piston rod 2 that interfaces with the end cap 6 is a hollow tube. The end cap 6 comprises a slot for the pneumatic piston rod 2 to sit in, as well as an inner rod that telescopes with this hollow tube portion of the pneumatic piston rod 2. The contact between the top of the pneumatic piston rod 2 and the end cap 6 allows the pneumatic piston rod 2 to rigidly transmit compression forces and movement to the upper segment 14 of the polycentric knee portion 14-18 but not tensile forces or movement. As such, when the actuator portion is locked in a fully compressed position, as is the case when the person using the prosthesis of the invention is seated, the pneumatic piston rod 2 is free to slide out of the slot in the end cap 6 along the inner telescoping rod. This allows the ankle and the knee to move independently of one another while still maintaining the alignment between the end cap 6 and the pneumatic piston rod 2.

In order to allow the actuator portion to transmit tensile forces, when the pneumatic piston rod 2 and end cap 6 are fully mated (i.e. when the pneumatic piston rod 2 sits fully in the slot) a radial hole on both parts align. A lock pin 8 can then be slid into these aligned holes, rigidly coupling the

pneumatic piston rod 2 to the end cap 6 and therewith to a proximal attachment point 4 on the upper segment 14 of the knee portion.

In some embodiments, the lock pin 8 comprises a spring-loaded button and a toggling pin device that toggles between an extended and collapsed state. The toggling device sits inside the inner rod of the end cap 6 such that when the toggle pin is extended, the pin protrudes through the hole in the pneumatic piston rod 2 and couples the two pieces together.

When the pin is toggled into the collapsed position, it retracts fully into the inner rod and the pneumatic piston rod 2 is no longer coupled to the end cap 6. The spring loaded button can be placed at the same position as the pin 8 shown in figure 1 and is used to toggle the inner device. This configuration allows the user to both couple and decouple the actuator portion by pushing the button inwards rather than pulling it outwards. This direction is both easier to apply force to biomechanically, and makes the prosthesis easier to use, also through clothing.

In order to allow the pneumatic cylinder 1 to stay in line with and posterior to the shank 24, a forked bracket 7 is used to connect the cylinder rod 3, which is rigidly attached to a bottom cylinder cap 12, to a distal actuator attachment point 5 on an anterior side of the lower segment 20 of the polycentric ankle portion. By using such a forked attachment, the distal attachment point 5 can move posterior-anteriorly with respect to the shank 24 without colliding with it or causing medial-lateral loading moments on the actuator portion. To provide a similar collision avoidance accommodation in the ankle itself, the flanges on the lower polycentric ankle portion that support the distal attachment point 5 are exterior to the polycentric ankle linkages 21, 22 which connect the upper segment 19 and lower segment 20 of the polycentric ankle, as shown in figure 2-Detail A.

To demonstrate the function of the prosthesis, the operation of the prosthesis for two activities of daily living, walking gait and stand-to-sit and sit-to-stand, will be described hereinafter with reference to figures 5-10 for the

walking motion and with reference to figures 11-17 for the stand-to-sit and sit-to-stand motions.

During gait as depicted in figures 5-10, the two compartments of the pneumatic cylinder 1 are connected by a first check valve 13' which allows for air to flow from the distal compartment to the proximal compartment but not in the other direction. This ensures that tensile forces can build in the cylinder 1 but compression forces cannot, and also serves to automatically set an energetically neutral position of the actuator portion to the most flexed position the actuator portion experiences.

A pressure release valve 27 may be applied in the piston head of the pneumatic cylinder 1, which can serve to vent air from the upper compartment to the lower compartment if the pressure in the upper compartment exceeds a certain predetermined value, limiting the neutral position to a certain predetermined state. Since the peak knee flexion and ankle flexion angles of a passive transfemoral prosthesis during swing exceed the desired neutral position of the actuator portion during gait (40 degrees of flexion at the knee and 20 degrees of flexion at the ankle), this combination of valves 13', 27 creates effectively a passive feedback controller that automatically adjusts the neutral actuator position back to the desired state during each step. This helps to negate the effect of air leakage out of the pneumatic system, which could otherwise cause drift in the neutral position over time. It also provides the advantage that the neutral position will be automatically and correctly set after the first step every time the prosthesis is switched into the gait function mode, negating the need for a complex active controller.

With the pneumatic control set as such, the actuator portion 1-3 and 9, 10 will produce a tension force anytime the leg is more extended than the 40 degrees knee flexion and 20 degrees ankle flexion neutral position. This tension force creates a flexion moment about both the knee and the ankle. This means that the actuator portion 1-3 and 9, 10 provides assistive knee and ankle flexion moments at early swing, see figure 9-('D' in figure 5), when the leg is still extended from toe-off, resulting in passive leg protraction. In late swing, see figure

6-('A- in figure 5), this same principle creates flexion moments that resist the knee extension, creating the desired knee damping while simultaneously harvesting energy back into the actuator portion 1-3 and 9, 10 in the form of compressed air.

5 At heel strike, the knee is already fully extended and the ankle gets fully extended by the ground reaction force. With the leg thus fully extended, the hydraulic valve 26 cooperating with the hydraulic cylinder 9 closes as will be explained hereinafter in the next paragraph, locking the actuator portion
10 1-3 and 9, 10 and storing the compressed air energy. The coupling that this lock creates between the knee and the ankle serves to keep the ankle locked in extension during stance, see figures 7 and 8 ('B' and 'C' in figure 5). This is because in this configuration the polycentric knee is already at its maximum
15 extension angle and the rigid-actuator coupling restricts the ankle from flexing without inducing further knee extension. At toe-off, the hydraulic valve 26 opens again as will be explained in the next paragraph, allowing the joints to flex for the swing phase, respectively shown in figures 9, 10 and 6 ('D', 'E' and
20 'A' in figure 5).

 The state (open/close) of the hydraulic valve 26 that locks the hydraulic cylinder can be controlled by a measured knee angle, such that the valve 26 locks when the knee is extended passed some critical extension angle and unlocks when
25 the knee flexes past this angle again. In this way, the leg is passively locked at heel strike when the knee fully extends at the end of swing (figure 6 and 'A' in figure 5), and unlocks when the ground reaction force causes the knee to buckle at toe-off. This angle dependent control could be implemented actively
30 with a microcontroller, or, preferably, could be implemented mechanically by placing a pin or rotary manual valve at the knee such that the valve state is flipped when the knee passes the critical extension angle. For this gait functionality, at the same time the tension coupling provided by the pin 8 in the end
35 cap 6 is always engaged.

 For the sitting and standing functionality as explained hereinafter with reference to figures 11-17, a second check valve 13'' is used between the upper and lower pneumatic cylinder 1 compartments such that air can flow freely from the upper

compartment to the lower compartment but not in the opposite direction. This allows compression forces to be built in the pneumatic cylinder 1, but not tensile ones. Likewise, when the actuator portion is compressed, this creates extension moments about both the knee and the ankle. The geometry of the polycentric knee and ankle joints, along with the distal and proximal attachment locations 4, 5 of the cylinder 1, can be specially designed such that the actuator portion 1-3 and 9, 10 produces knee and ankle joint moment profiles during the sit-to-stand movement that bio-mimetically match the joint moment profiles produced by a healthy leg during this movement.

The geometries of the polycentric joints contribute to the design of these joint moment profiles by determining the instantaneous center of rotation of both joints throughout the movement, and the distal and proximal actuator attachment points 4, 5 contribute by controlling the line of action of the actuator portion 1-3 and 9, 10. The piston-cylinder geometry similarly contributes by determining the force-length relation of the actuator portion. For this functionality, it is important that the actuator portion 1-3 and 9, 10 is not rigidly attached to the shank 24, because the lack of this connection allows the line of action of the pneumatic cylinder 1 at the ankle portion 19-23 to be adjusted by the angle of the knee portion 14-18 with reference to the shank 24, therefore making the moment arm at the ankle a function of both knee and ankle angle. This is beneficial because the moment arm profile at the ankle required to produce biomimetic joint profiles is not a function of ankle angle alone.

The hydraulic lock valve 26 remains open for the duration of the standing and sitting actions shown in figure 13 ('G' in figure 11), but closes at seat-on shown in figure 14 ('H' in figure 11) and remains closed while the user is seated shown in figures 15 and 16 ('I' and 'J' in figure 11). This allows energy to be harvested during the stand-to-sit movement, stored while seated, and then released to power the sit-to-stand movement.

For this standing-to-sitting or sitting-to-standing function, the neutral position of the actuator portion is where the knee and ankle are both fully extended, such that no actuator

forces are produced when standing shown in figure 12 ('F' in figure 11) and the maximum actuator forces are produced when seated as shown in figures 15 and 16 ('I' and 'J' in figure 11).

Since only compressive forces are required of the actuator portion 1-3 and 9, 10 during this functionality, the tension coupling pin 8 can be removed/disengaged. This allows the leg to be moved around and extended by the user while seated without the constraints imposed by the rigid coupling of the locked actuator. As with the stance control, the hydraulic lock valve 26 in this function could be automatically engaged once the knee passed a certain critical knee flexion angle corresponding to the seat on position of figure 14 ('H' in figure 11). This could again be accomplished either through a microcontroller, or mechanically by a mechanical rotary or detent pin valve. For safety, however, an additional input may be required at seat-off according to figure 17 ('K' in figure 11) to open the hydraulic valve 26. This input can either come directly from the user, such as through a mechanical button, or from a computerized intention detection algorithm.

To switch between the sit-to-stand and gait functions, attached to the end cap 6 is preferably a single 2/2 spool valve 13 with the required first check valve 13' for gait in one position and the inverse second check valve 13'' in the other position for sit-to-stand. This spool valve can be actuated by a toggle button that is rigidly attached to the tension coupling pin 8. This means that the user can perform both of the required changes for the switch between gait and sit-to-stand (tension coupling/decoupling and pneumatic valve state toggling) with a single button press.

Although the invention has been discussed in the foregoing with reference to an exemplary embodiment of the method of the invention, the invention is not restricted to this particular embodiment which can be varied in many ways without departing from the invention. The discussed exemplary embodiment shall therefore not be used to construe the appended claims strictly in accordance therewith. On the contrary the embodiment is merely intended to explain the wording of the appended claims without intent to limit the claims to this exemplary embodiment. The scope of protection of the invention shall therefore be

construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of the claims shall be resolved using this exemplary embodiment.

- 5 List of parts as labelled in figure:
1. Pneumatic Cylinder
 2. Pneumatic Piston Rod
 3. Pneumatic Cylinder Rod
 4. Proximal Actuator Attachment Hinge
 - 10 5. Distal Actuator Attachment Hinge
 6. Proximal Actuator Attachment End Cap
 7. Forked Distal Actuator Attachment Bracket
 8. Tension Coupling/Decoupling Pin
 - 15 9. Hydraulic Cylinder
 10. Hydraulic Piston Rod
 11. Rigid Coupling Between the Hydraulic and Pneumatic Piston Rods
 12. Cylinder End Caps
 - 20 13. Pneumatic Control Spool Valve
 14. Polycentric Knee Upper Segment
 15. Polycentric Knee Lower Segment
 16. Polycentric Knee Posterior Link
 - 25 17. Polycentric Knee Anterior Link
 18. Polycentric Knee Hinge Joints
 19. Polycentric Ankle Upper Segment
 20. Polycentric Ankle Lower Segment
 - 30 21. Polycentric Ankle Posterior Link
 22. Polycentric Ankle Anterior Link
 23. Polycentric Ankle Hinge Joints
 24. Shank Portion
 25. Pyramidal Adapters
 - 35 26. Hydraulic Lock Valve 27. Pressure Release Valve

CLAIMS

1. A transfemoral knee-ankle prosthesis, comprising a knee portion (14-18), an ankle portion (19-23), an actuator portion (1-3, 9, 10), and a shank portion (24), wherein the shank rigidly connects the knee portion with the ankle portion, wherein the actuator portion (1-3, 9, 10) is biarticular and connects the knee portion (14-18) to the ankle portion (19-23) without an intermediate connection to the shank (24),
10 **characterized in that** the actuator portion (1-3, 9, 10) comprises a bidirectional pneumatic cylinder (1) and a hydraulic locking cylinder (9), which are rigidly coupled to each other with cylinder end caps (12) provided on opposite sides of the pneumatic cylinder (1) and the hydraulic cylinder (9), wherein
15 the hydraulic locking cylinder (9) is provided with an hydraulic locking valve (26), and that during gait, opening and closing of the hydraulic locking valve (26) is dependent on a measured angle of the knee portion with reference to the shank (24).

2. The knee-ankle prosthesis of claim 1, **characterized in that** the pneumatic cylinder (1) comprises a pneumatic piston rod (2), and the hydraulic locking cylinder (9) comprises an hydraulic piston rod (10), and that the pneumatic piston rod (2) and the hydraulic piston rod (10) are rigidly coupled to each other with a coupling (11).

25 3. The knee-ankle prosthesis of any one of claims 1-2, **characterized in that** between the actuator portion (1-3, 9, 10) and the knee portion (14-18) a releasable connector (6) is provided.

30 4. The knee-ankle prosthesis of claim 2 and 3, **characterized in that** the releasable connector (6) is connectable to the pneumatic piston rod (2) with a controllable lock pin (8).

35 5. The knee-ankle prosthesis of claim 4, **characterized in that** the controllable lock pin (8) is movable in or out of aligned holes in the releasable connector (6) and the pneumatic piston rod (2).

6. The knee-ankle prosthesis of claim 4 or 5, **characterized in that** the controllable lock pin (8) is one selected from a spring-loaded button and a toggling pin device.

7. The knee-ankle prosthesis of any one of claims 1-6, **characterized in that** the knee portion (14-18) is polycentric pivotable with reference to the shank (24).

8. The knee-ankle prosthesis of any one of claims 1-7, **characterized in that** the ankle portion (19-23) is polycentric pivotable with reference to the shank (24).

9. The knee-ankle prosthesis of claim 7 or claim 8, **characterized in that** at least one of the knee portion (14-18) and the ankle portion (19-23) comprises a four bar linkage connecting a lower segment and an upper segment of the knee portion and ankle portion, respectively.

10. The knee-ankle prosthesis of any one of claims 7-9, **characterized in that** each of the knee portion and the ankle portion comprises a four bar linkage, wherein a lower segment (15) of the knee portion and an upper segment (19) of the ankle portion are connected to each other through the shank (24).

11. The knee-ankle prosthesis of claim 10, **characterized in that** a cylinder rod (3) of the pneumatic hydraulic cylinder (1) connects with a forked bracket (7) anterior to the shank (24) to opposite sides of the ankle portion (19-23).

12. The knee-ankle prosthesis of claim 11, **characterized in that** the forked bracket (7) is connected to an attachment point (5) that is exterior of the linkages of the four bar linkage connecting the upper segment (19) and the lower segment (20) of the ankle portion.

13. The knee-ankle prosthesis of any one of claims 1-12, **characterized in that** to assist the gait functionality of the prosthesis, the pneumatic cylinder (1) is connected to a first check valve (13') enabling air to flow from a distal compartment to a proximal compartment separated by a piston from the distal compartment, wherein the distal compartment is more distant from the knee portion (14-18) than the proximal compartment.

14. The knee-ankle prosthesis of any one of claims 1-13, **characterized in that** the pneumatic cylinder (1) is provided with a pressure release valve (27) which serves to vent air from the proximal compartment to the distal compartment if a pressure in the proximal compartment exceeds a predetermined value.

15. The knee-ankle prosthesis of any one of claims 1-14, **characterized in that** to enable a sitting and standing functionality of the prosthesis, the pneumatic cylinder (1) is connected to a second check valve (13'') enabling air to flow from a proximal compartment to a distal compartment separated by a piston from the proximal compartment, wherein the distal compartment is more distant from the knee portion (14-18) than the proximal compartment.

16. The knee-ankle prosthesis of any one of claims 13-15, **characterized in that** the first check valve (13') and the second check valve (13'') form part of a single 2/2 spool valve (13).

17. The knee-ankle prosthesis of any one of claims 1-16, **characterized in that** during sitting the hydraulic locking valve (26) is closed.

18. The knee-ankle prosthesis of claim 17, **characterized in that** closing of the hydraulic locking valve (26) during sitting is depending on a measured angle of the knee portion with reference to the shank (24).

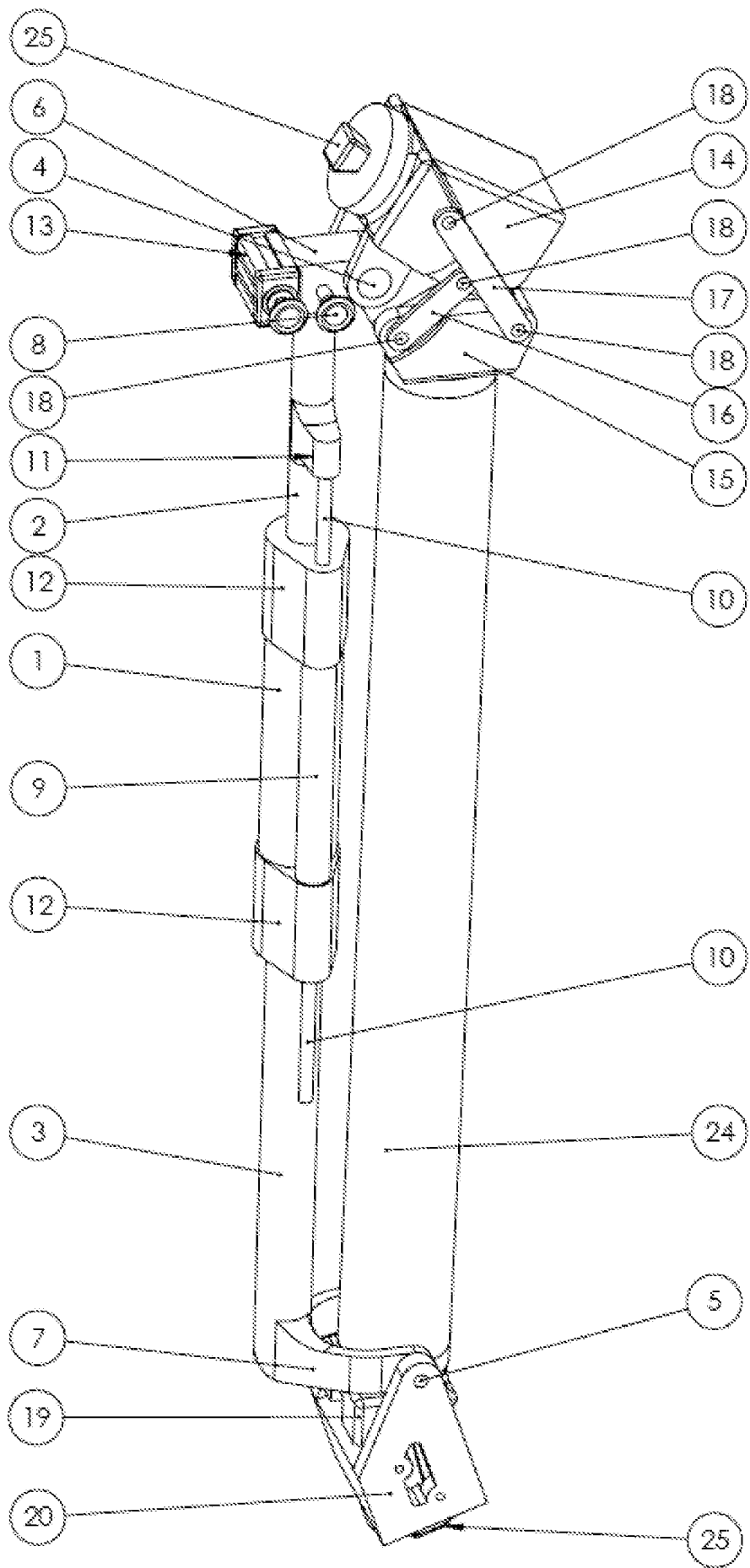


Fig. 1

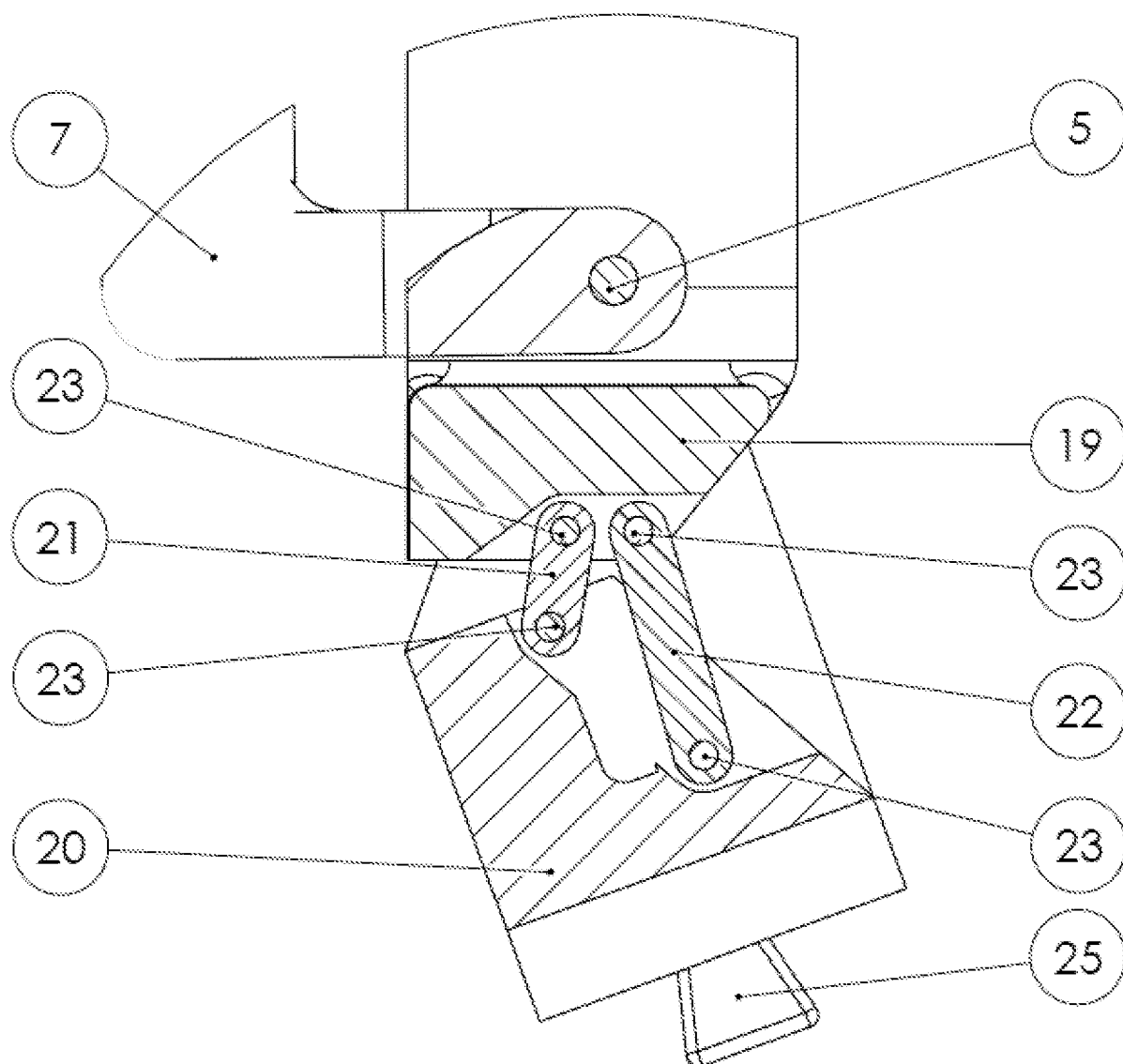


Fig. 2

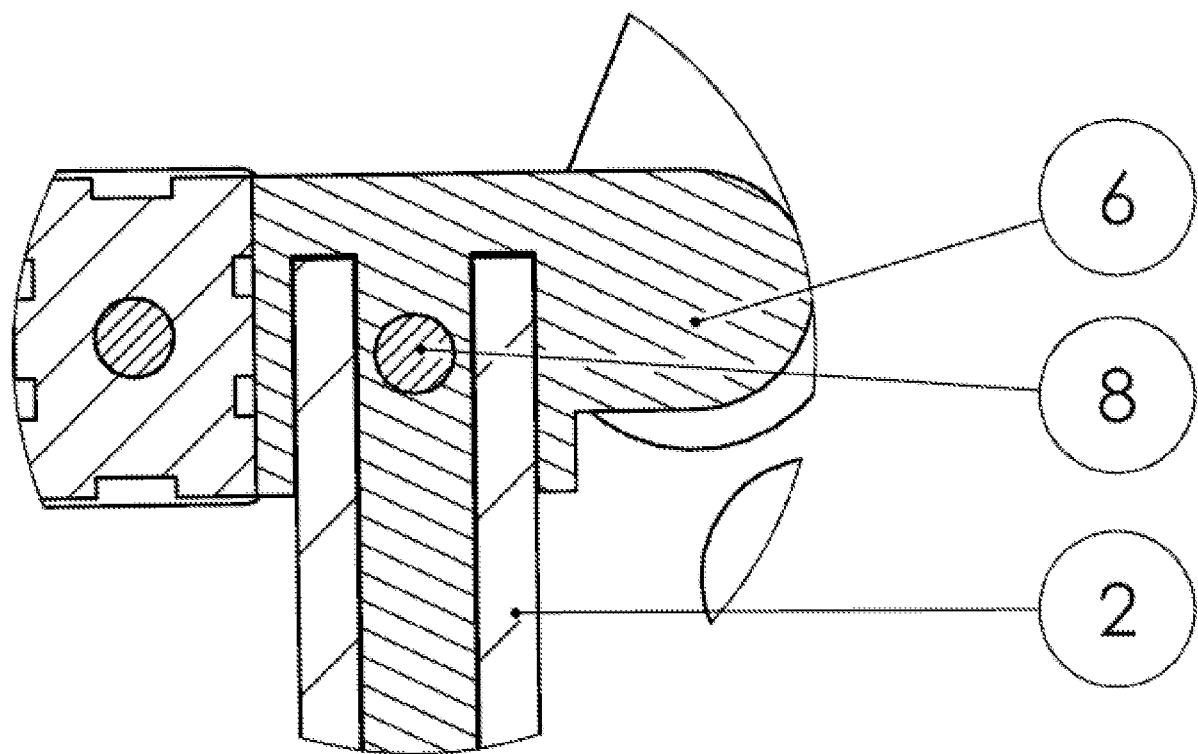


Fig. 3

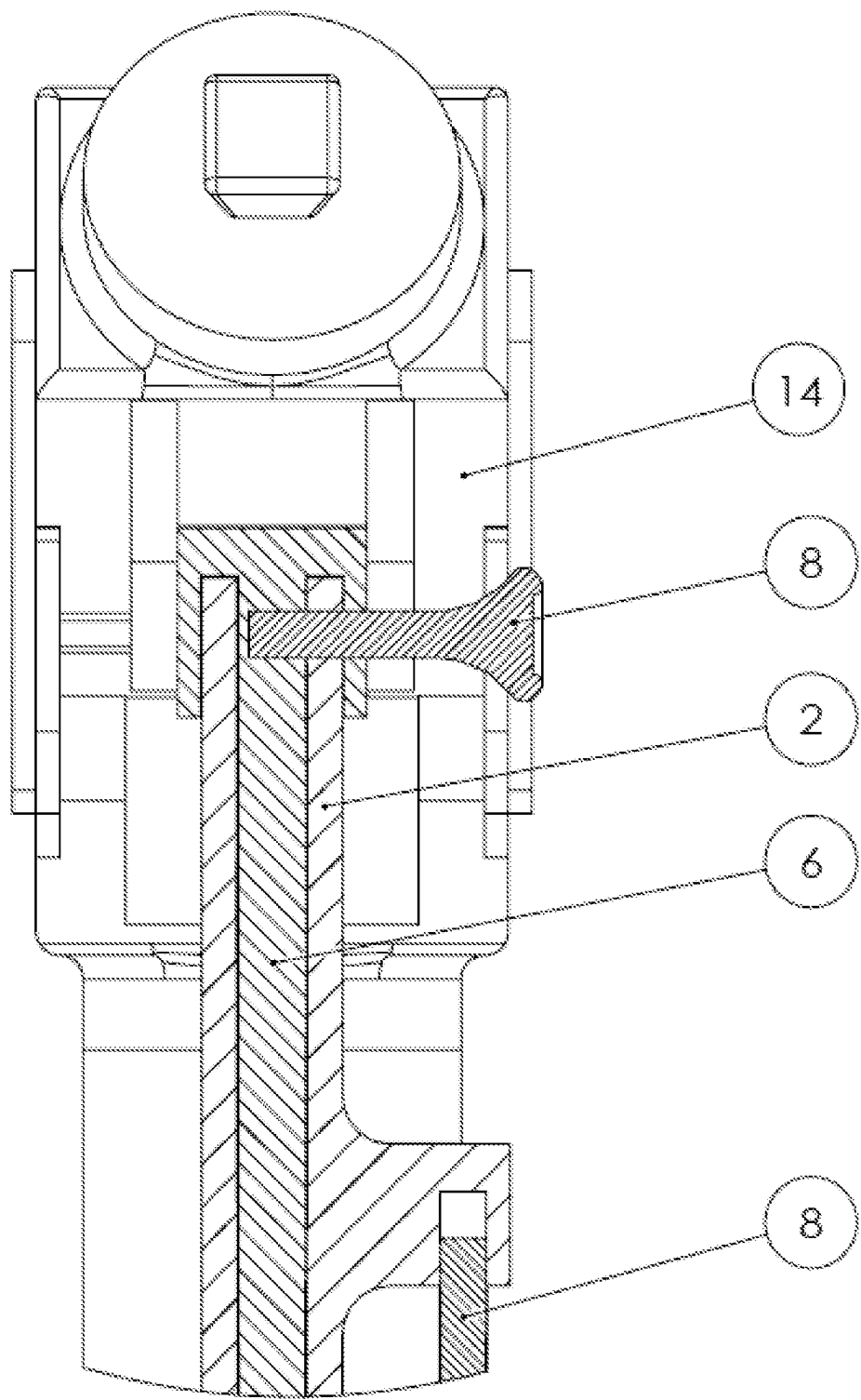


Fig. 4

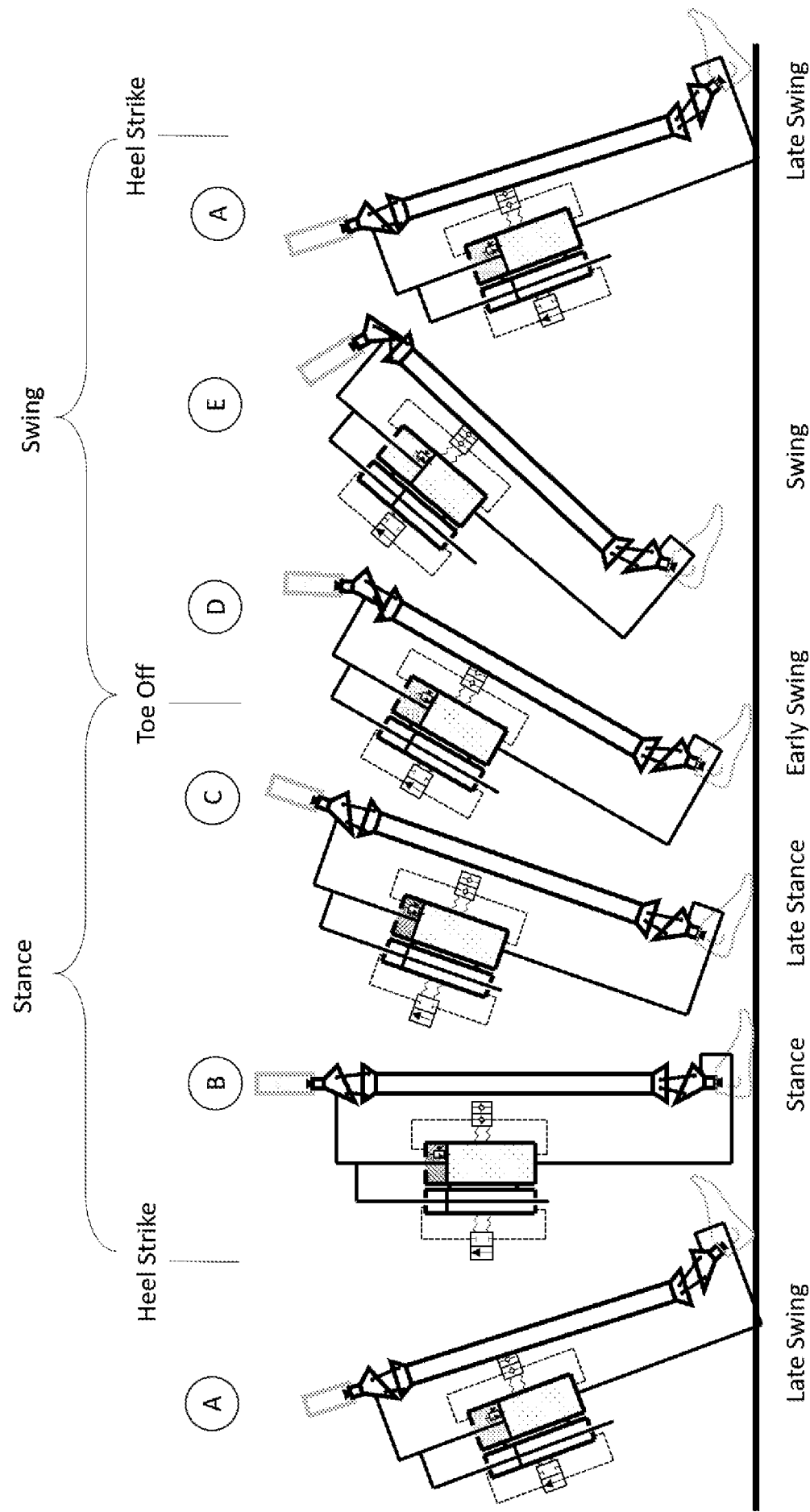


Fig. 5

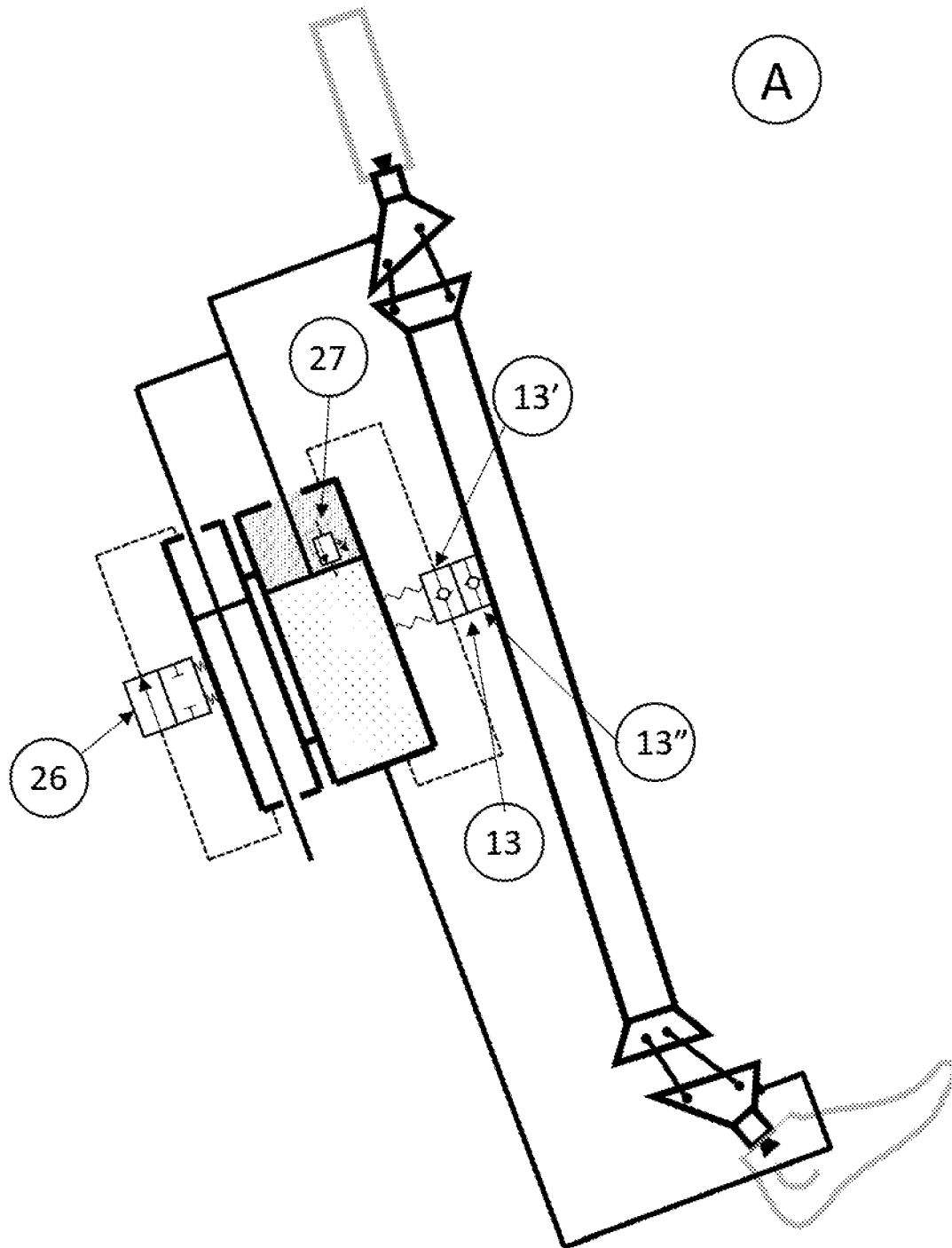


Fig. 6

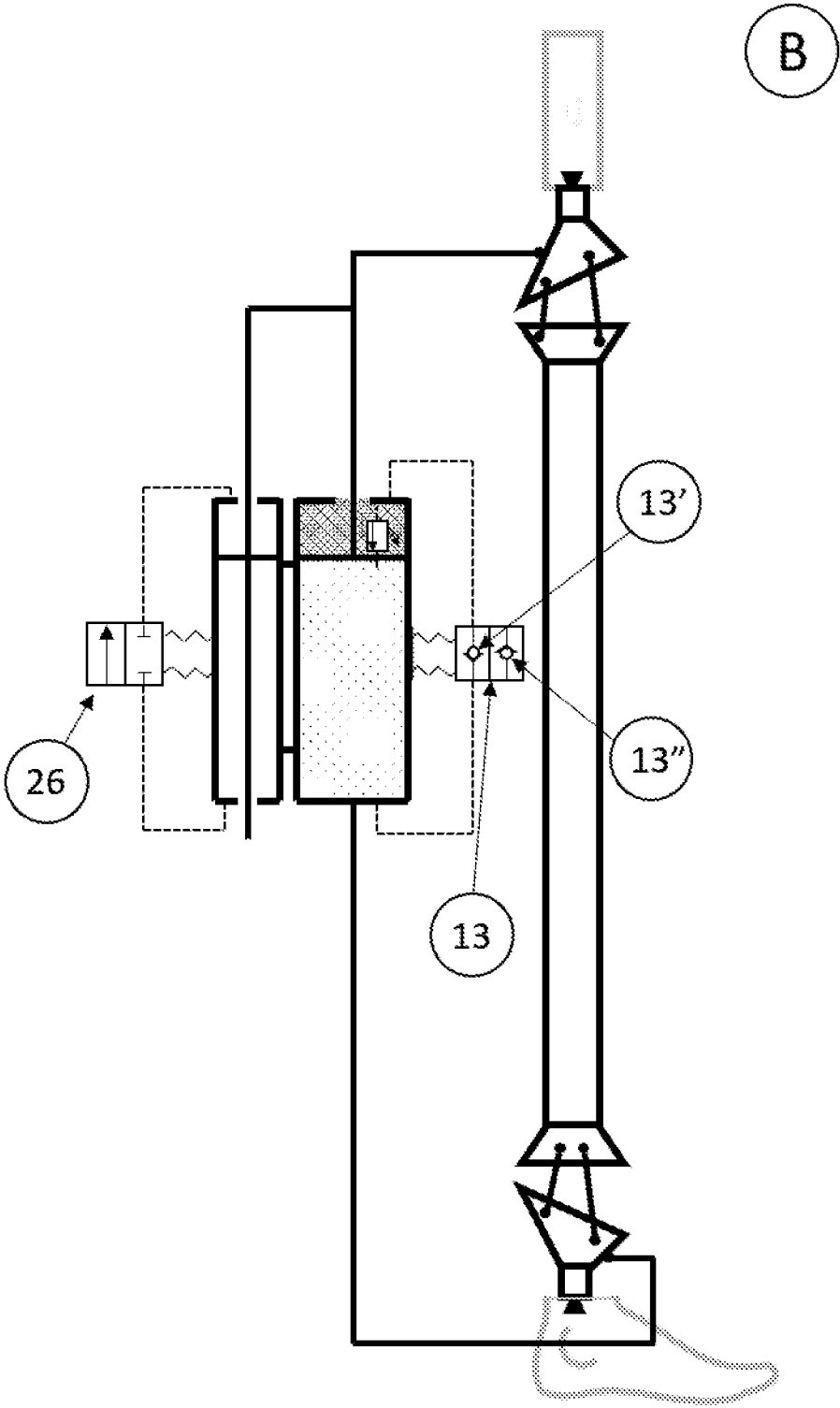


Fig. 7

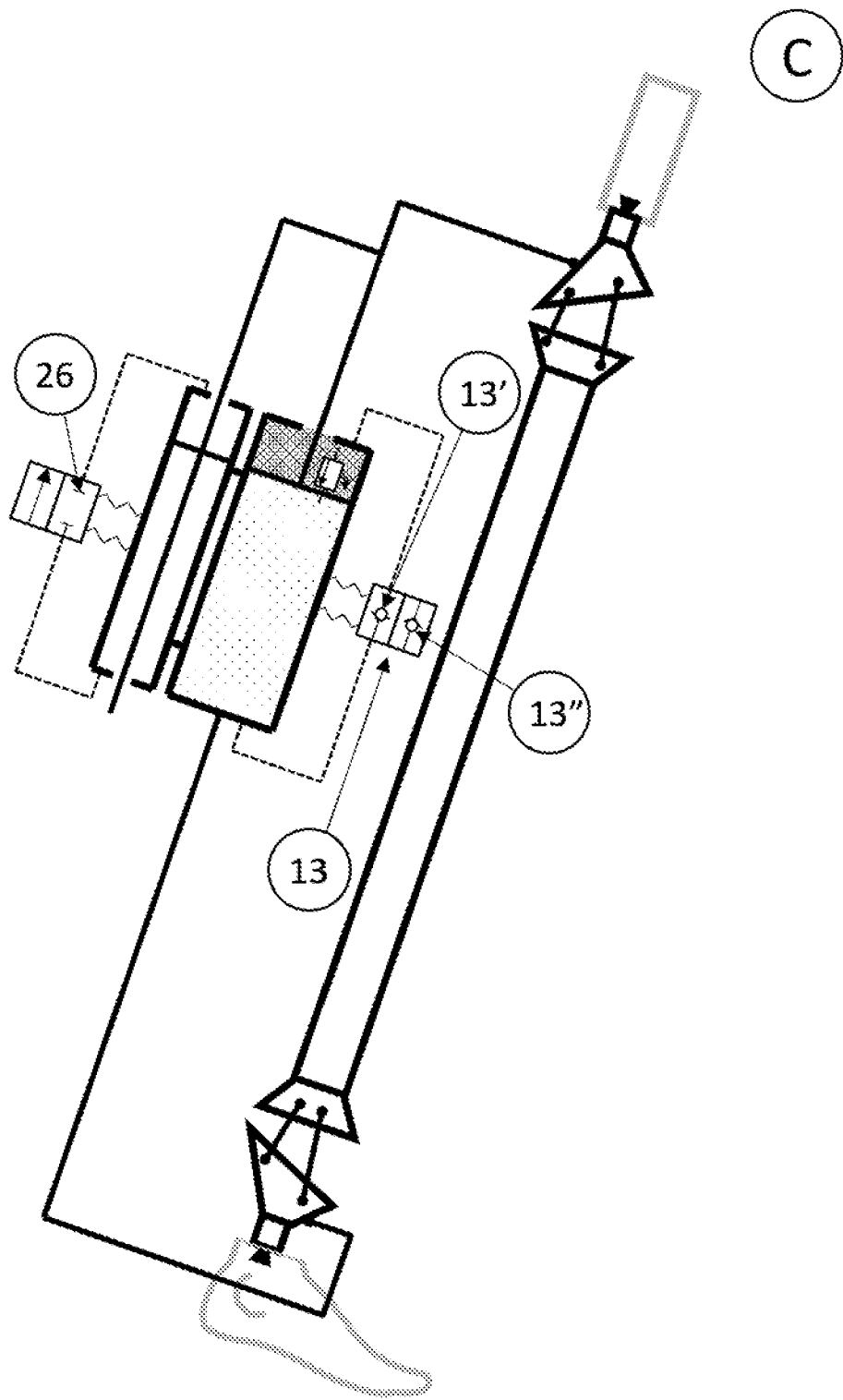


Fig. 8

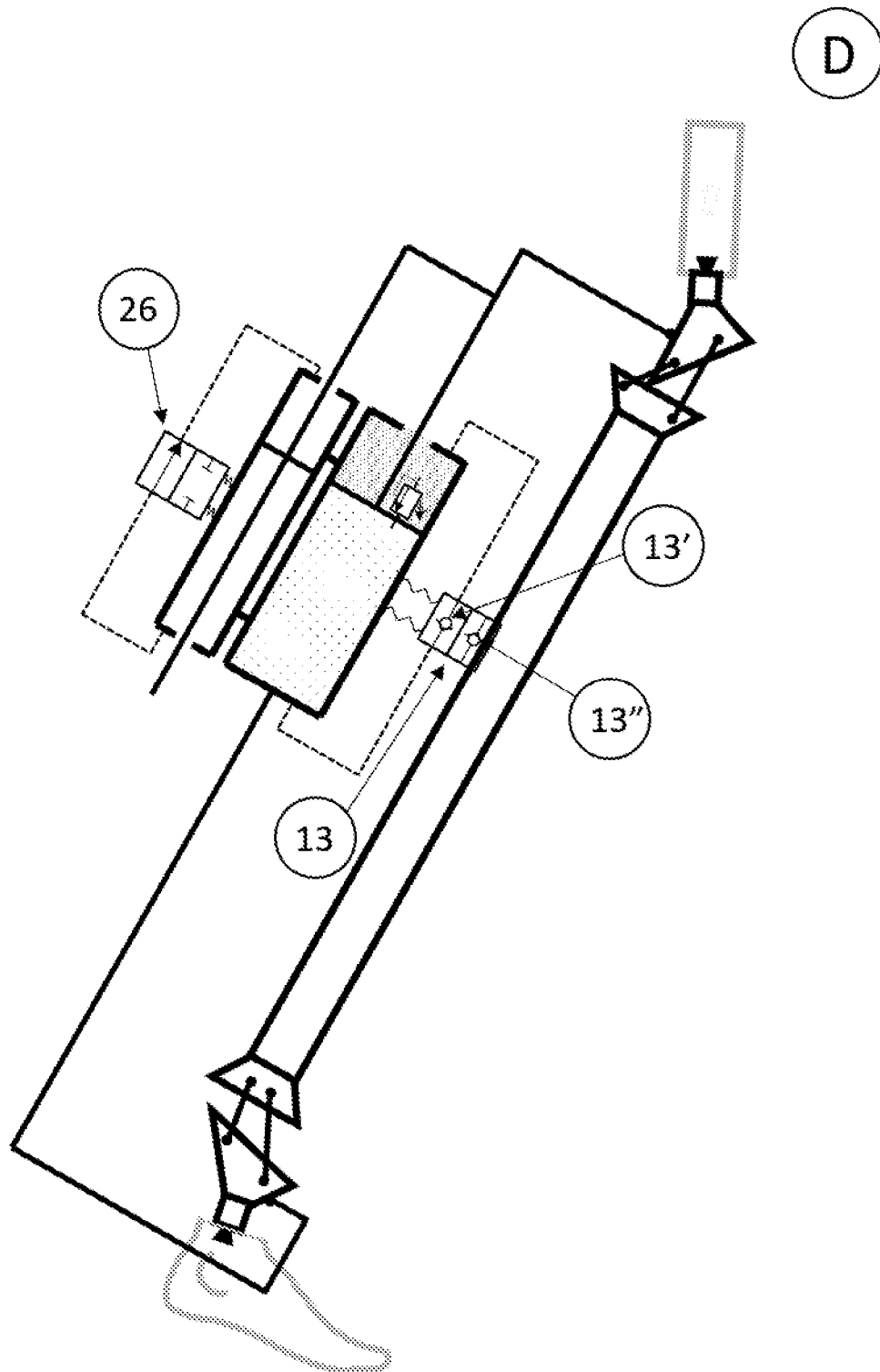


Fig. 9

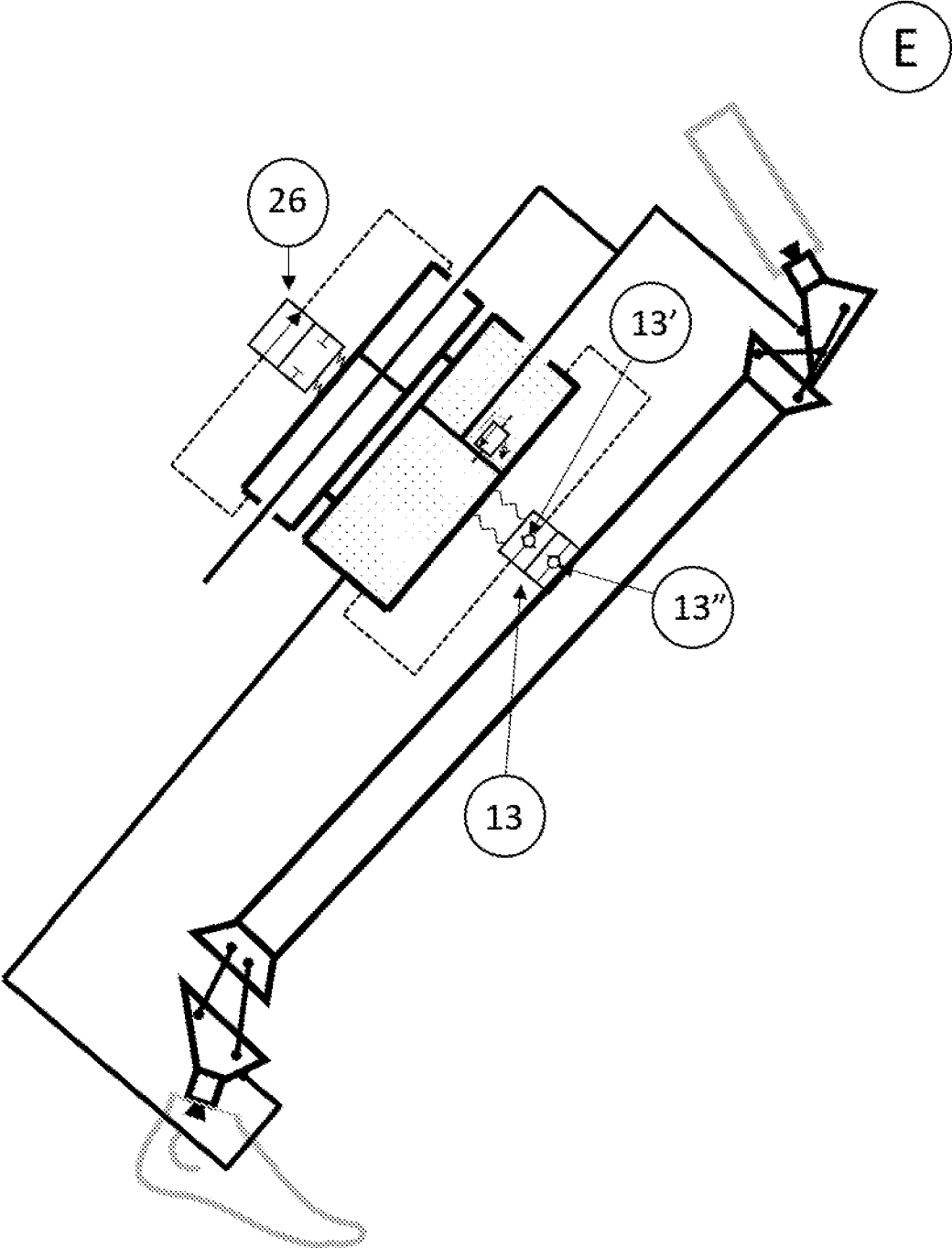


Fig. 10

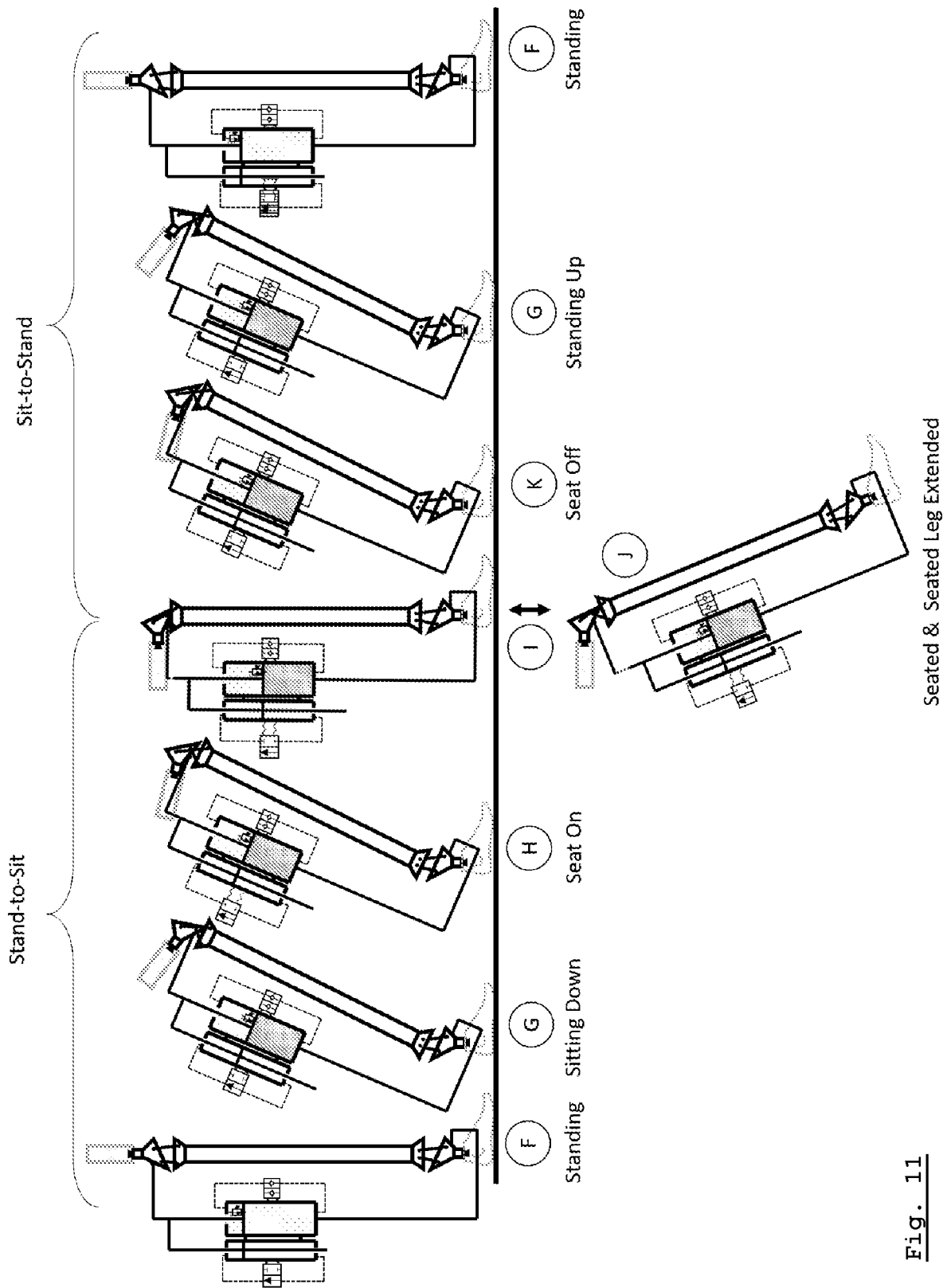


Fig. 11

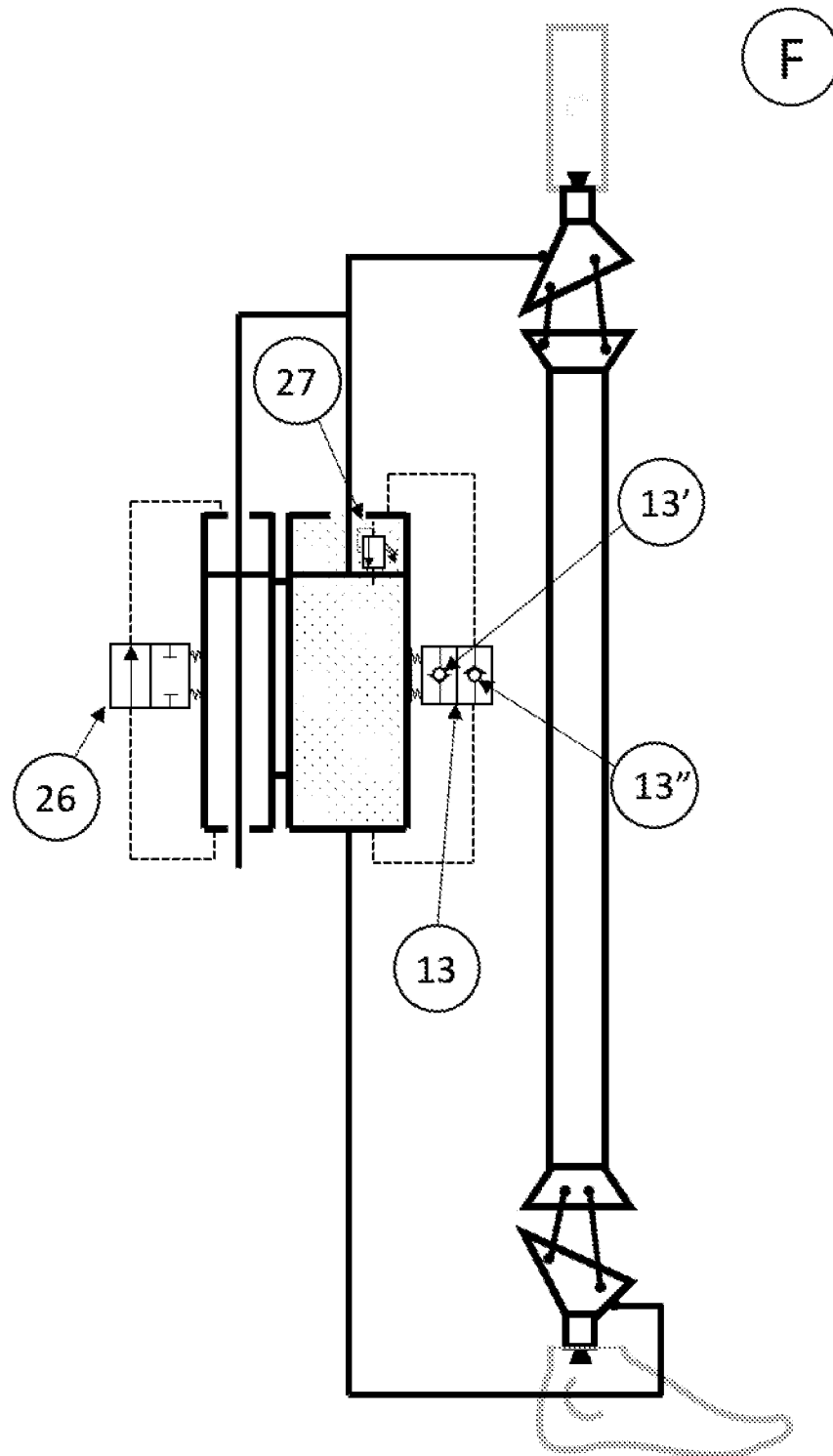


Fig. 12

G

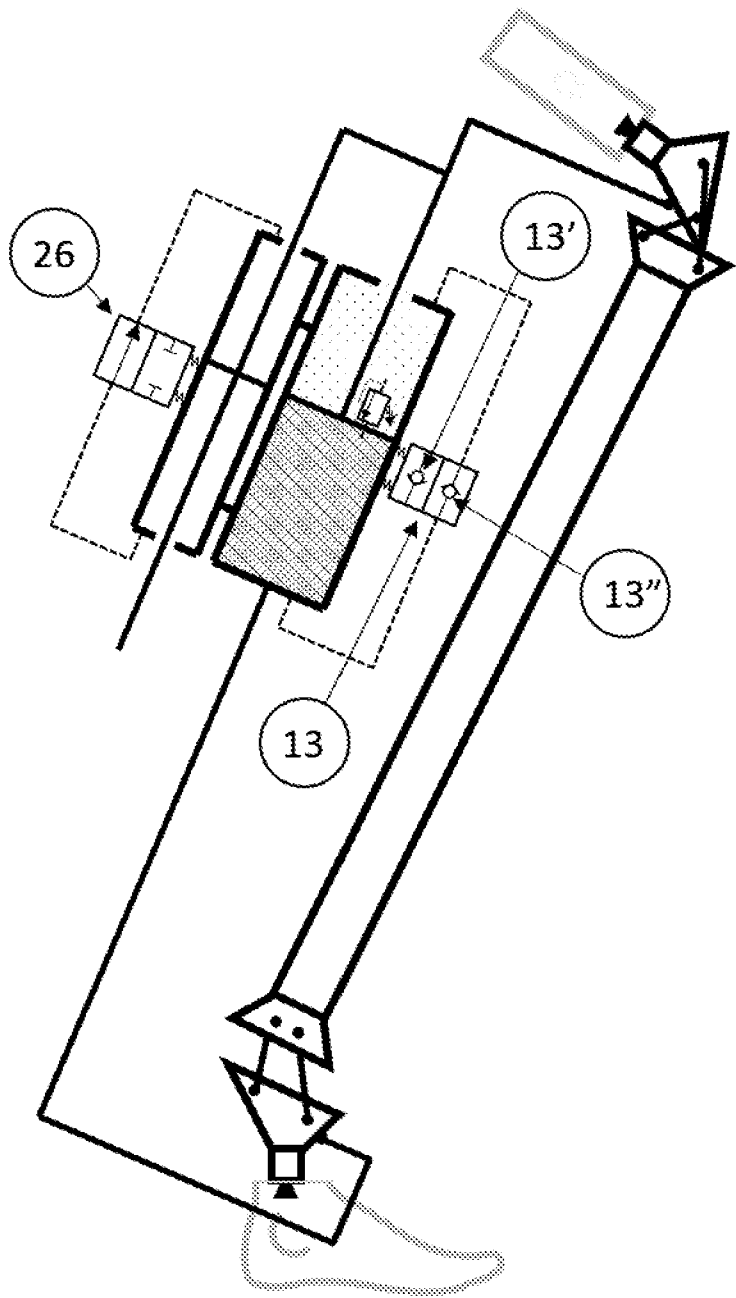


Fig. 13

H

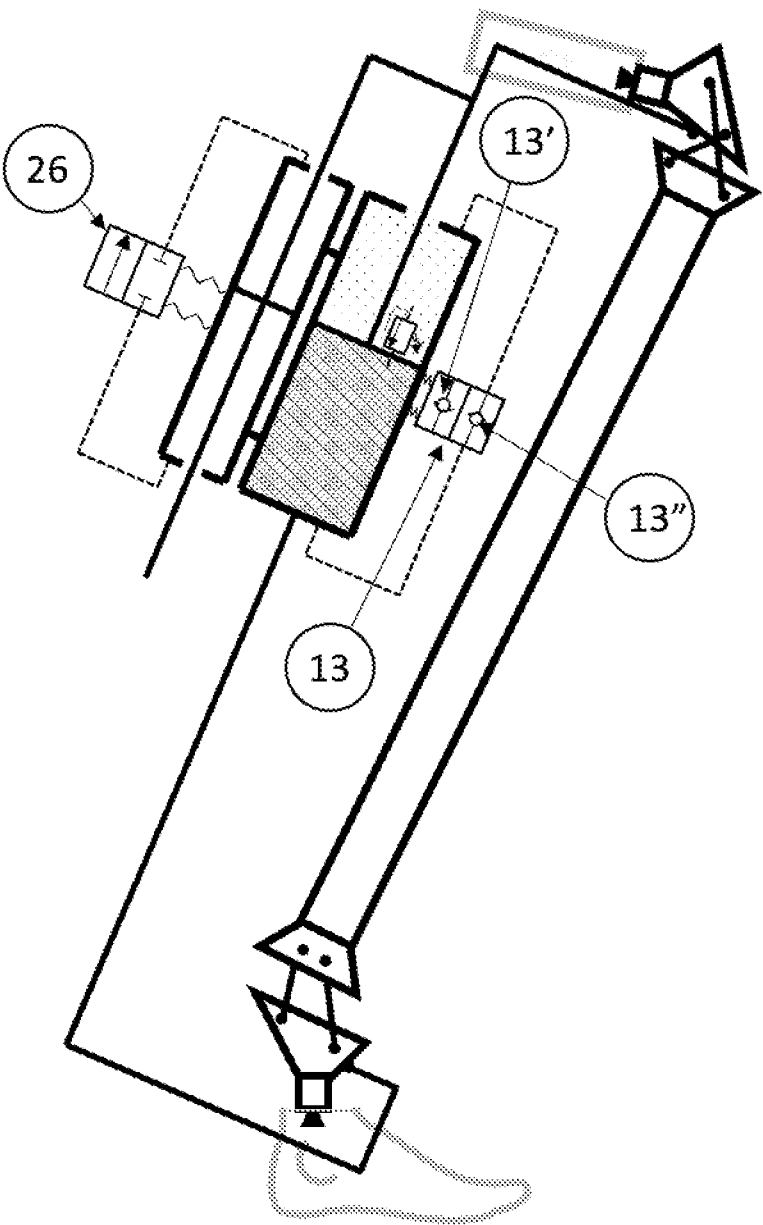


Fig. 14

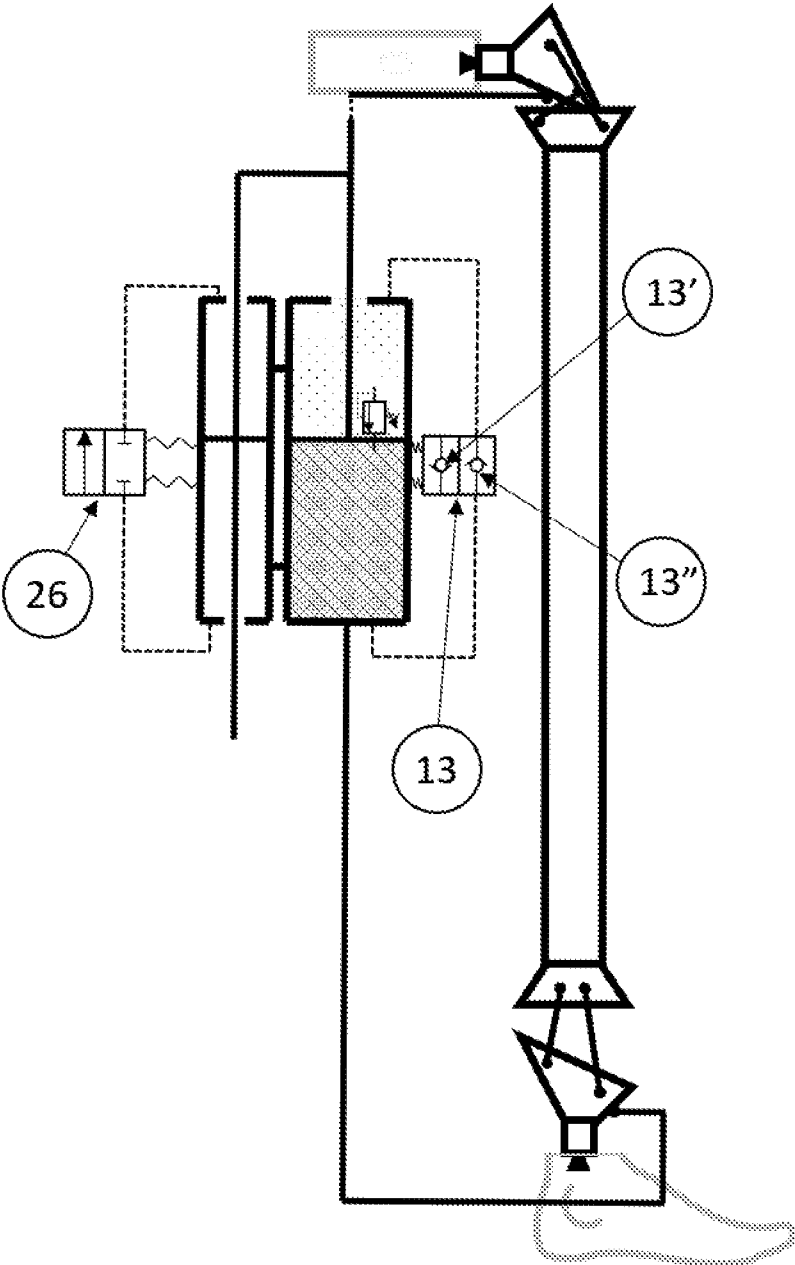
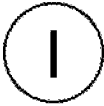


Fig. 15

J

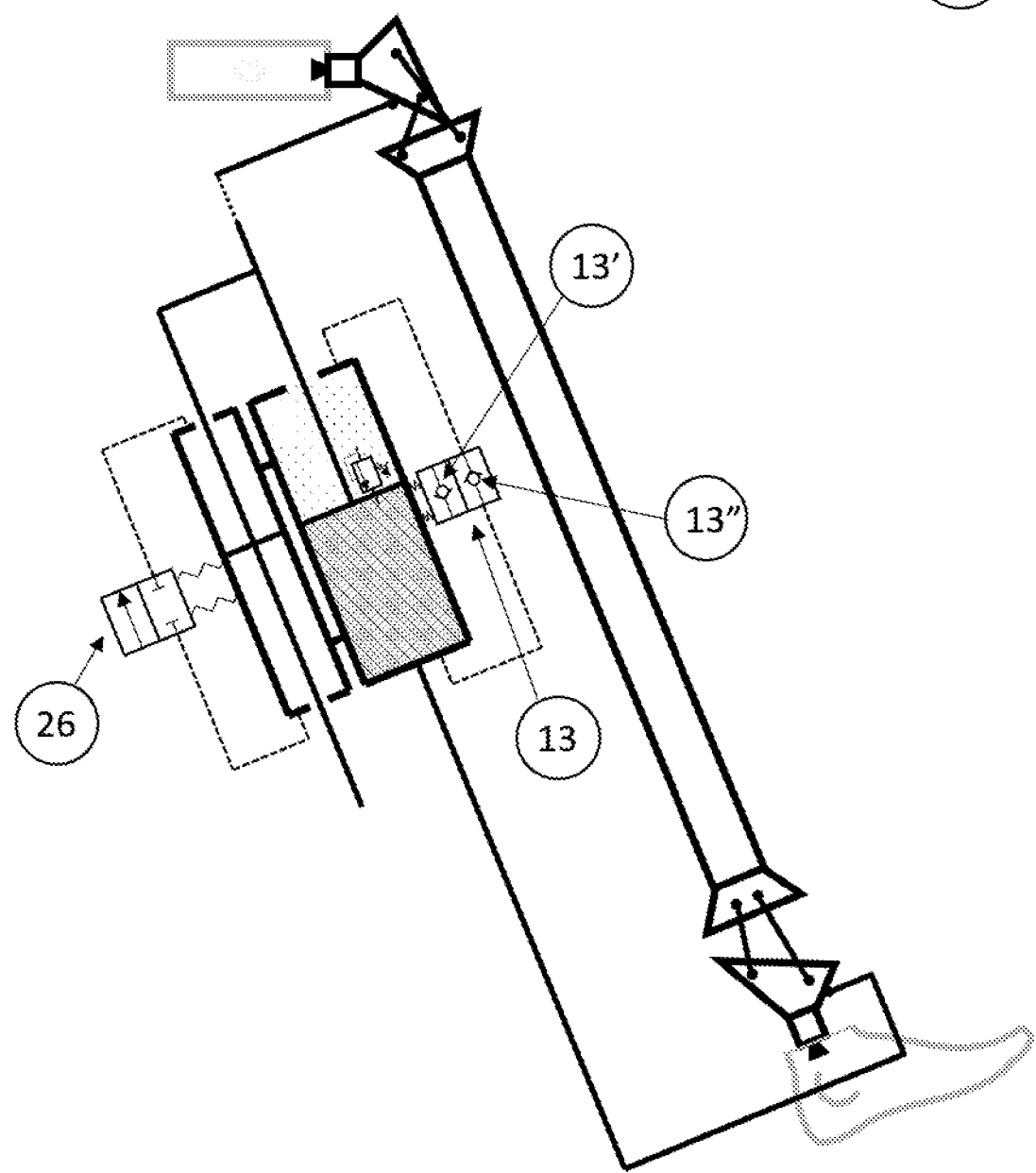


Fig. 16

K

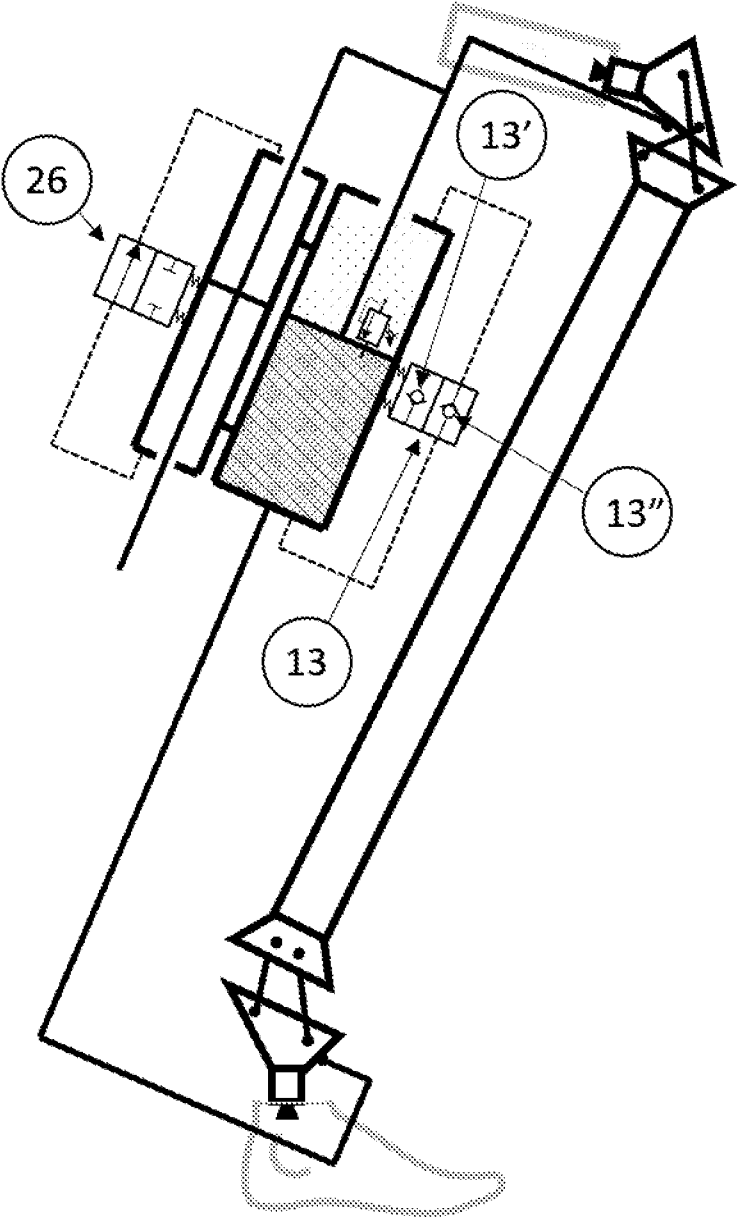


Fig. 17

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2021/050782

A. CLASSIFICATION OF SUBJECT MATTER INV. A61F2/60 A61F2/64 A61F2/66 A61F2/74 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) A61F		
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		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2018/133031 A1 (BONNET XAVIER [FR] ET AL) 17 May 2018 (2018-05-17) figure 1 paragraphs [0028] - [0032] -----	1-18
X	US 2016/228265 A1 (HERR HUGH M [US] ET AL) 11 August 2016 (2016-08-11) figures 19-21, 43-50 paragraphs [0116] - [0119], [0134] - [0139], [0182] - [0185] -----	1-18
X	WO 2012/177125 A1 (UNIV TWENTE [NL]; STICHTING TECH WETENSCHAPP [NL] ET AL.) 27 December 2012 (2012-12-27) figures 5, 6A-12 page 11, line 12 - page 12, line 11 ----- -/-	1-18
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 24 March 2022		Date of mailing of the international search report 04/04/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Barnas, Christoph

INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2021/050782

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/241242 A1 (HERR HUGH M [US] ET AL) 23 September 2010 (2010-09-23) figures 14A-14D paragraphs [0188] - [0192] -----	1-18

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Information on patent family members

International application No

PCT/NL2021/050782

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