(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 104 819 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
18.03.2020 Bulletin 2020/12

(21) Application number: **14714804.3**

(22) Date of filing: **14.02.2014**

(51) Int Cl.:
A61H 1/02 *(2006.01)*

(86) International application number:
PCT/PL2014/050007

(87) International publication number:
WO 2015/122786 (20.08.2015 Gazette 2015/33)

(54) **DEVICE SUPPORTING PHYSICAL ABILITIES OF THE LOWER LIMBS**

VORRICHTUNG ZUR UNTERSTÜTZUNG DER PHYSISCHEN FÄHIGKEITEN DER UNTEREN GLIEDMASSEN

DISPOSITIF DE SOUTIEN DES CAPACITÉS PHYSIQUES DES MEMBRES INFÉRIEURS

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **11.02.2014 PL 40714214**

(43) Date of publication of application:
21.12.2016 Bulletin 2016/51

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Printed by Jouve, 75001 PARIS (FR)

Description

[0001] This invention relates to a device supporting physical abilities of the lower limbs, driving the lower limb joints in the sagittal plane and supporting the sitting position and standing up.

[0002] Manipulators used in the rehabilitation of the lower limbs are known. Those devices consist of motorised levers fastened in the hip joint and in the knee joint to the side plane of the left and right lower limb. The devices fitted with such drive systems prohibit performing other movements than walking and they require to use a treadmill or a foundation in order to ensure that the user's feet are supported.

[0003] Driving only the hip and knee joints of both lower limbs does not provide the full control over the manner of treading, limits the range of exercises to walking, and generates adverse forces resulting from hitting the treadmill with the feet.

[0004] A powered orthosis is known from description WO 2008 124025, this is adapted to be secured to a corresponding body portion of a user for guiding motion of the user. The orthosis comprises a plurality of structural members and one or more joints adjoining adjacent structural members. Each joint has one or more degrees of freedom and a range of joint angles. Each joint comprises at least one actuator governed by at least one controller for controlling the joint angle. The joint actuator controllers are synchronized to cause the corresponding joint actuators to generate forces for assisting the user to move the orthosis at least in part under the user's power along a desired trajectory within an allowed tolerance.

[0005] An apparatus for treadmill training of walking-disabled patients, comprising a treadmill, a relief mechanism for the patient, and a driven orthotic device is known from description US 6821233. The device automatically guides the patient legs on the treadmill. The orthotic device comprises a hip orthotic device and two leg parts, as well as hip drives and knee drives. Stabilizing members maintain the patient's balance. The length of the orthotic device members is adjustable to the patient's height.

[0006] WO 01/91675 discloses a rehabilitation device for persons with paresis of lower limbs enabling them to walk, comprising essentially rocking elements having at their lower part foot elements with platforms for user's feet. Said rocking elements are connected, at their upper part by a frame constituting a jacket. The device has two basic and two auxiliary rocking elements, where the basic elements consist of two pairs of members, the upper pair and the lower pair of members, where the members of each pair are connected to each other by means of a pivot joint. The auxiliary rocking elements consist of one pair of members, each member of the pair connected at their lower portion by means of a pivot joint to connectors, which are connected in turn to upper members of basic rocking elements, which are connected, at their lower portion, to foot elements with foot platforms. The uppermost portion of basic and auxiliary rocking elements are connected, by means of pivot joints to angular connectors having bolts rotatably mounted in clasps, slidably mounted on the jacket frame. The auxiliary rocking elements are connected, at their lower portion to pistons of spring, gas or hydraulic shock absorbers or to pneumatic or hydraulic cylinders, acting as servomotors, which, at their other ends are pivotally connected to said foot elements, at a distance from connecting pivots of basic rocking elements. Said foot elements consist each of a trapezoidal frame with two pairs of arms, the first pair of arms being parallel to the axis of the person's movement, i. e. axis of symmetry of the device, and the second pair of arms having supports being able to extend outwardly in relation to the axis of symmetry of the device, and where the one, longer arm of the first pair having pivotal joints for the basic rocking elements and shock absorbers, and the second, shorter arm having a foot platform secured thereto. The said foot elements each, having flexible pads underneath, situated, one just under the foot platform and the two other at the ends of outwardly extending arms and where the latter pads being slightly lower than the former ones. The auxiliary rocking elements are interconnected by means of horizontal bipartite interconnections, to which is fixed a plate constituting a seat, in a manner that the basic and auxiliary rocking elements constitute symmetrical left hand and right hand side of the device.

[0007] The purpose of the invention is to design a device that enables the user to stand up, walk, sit down and other movements of the lower limbs that are in line with the anatomy, for instance a knee bend, a one-leg stand, with the possibility to eliminate the contact of feet with the foundation.

[0008] The device supporting physical abilities of the lower limbs according to the invention comprises a stationary non-movable stand, a lumbar support, a seat, and parallel movable members adjoining the lower limbs of the user, divided into segments corresponding to the parts of the lower limb and pivotal articulations connected in a self-aligning manner, fitted with drives for the relevant joints.

[0009] According to the invention, the device has a vertical mechanism that enables the user to be lifted, a seat mechanism that enables the user to be supported and lifted while sitting down and standing up and pivotally connected couplings of three joints - the hip joint, the knee joint and the ankle joint - allowing the movement in the sagittal plane.

[0010] The lumbar support, movable in the vertical plane, is connected in a hip articulation through arms to mobile couplings of the lower limbs, a back pusher movable in the vertical plane and sagittal plane is connected through the lumbar support with arms, and the seat movable in the vertical plane is connected to a bracket.

[0011] The essence of the solution according to the invention consists in that the lumbar support, the back pusher, the arms and the seat are mounted on common

vertical guide rails of the stand. The back pusher has a variable position, successively in the frontal plane and in the sagittal plane,
The arms are pivotally mounted in the guide rails, movable to part sideways.
The device has hip side clamps with a variable position successively in the frontal and the sagittal plane.

[0012] Each segment of a member that is adjacent to the lower limbs of the user consists of a thigh coupling, a shin coupling and a foot coupling, in addition the thigh coupling and the shin coupling have a variable, adjustable length through a prismatic articulation interlocked with a clamp, and a shin prismatic articulation.
A magnetic barrier is situated in the base of the stand.
The device has thigh and shin cuffs that can be shifted in the frontal and in the sagittal plane. The device has foot supports that can be shifted in the frontal plane and in the side plane.
The ankle joint articulation has a drive situated on the side plane of the member that is parallel to the user's limbs. A belt rotary gear constitutes the ankle joint articulation and the knee joint articulation. The hip joint articulation is a backlash-free cycloidal gear connected to a servomotor with a vibration-dampening belt gear.

[0013] The solution according to the invention - by synchronized driving of the hip, knee and ankle joints of the user in accordance with the anatomy, or the correct human gait pattern - enables the lower limbs to be moved in a set manner allowing standing up, walking, knee bending, alternating leg swings and sitting down in accordance with the abilities of the human anatomy and the anatomical movement and the range of these movements. Driving all lower limb joints in the sagittal plane and lack of contact with the foundation and its adverse impact during treading, consequently provides great possibilities of programming any lower limb movements, in accordance with the human anatomy.

[0014] The subject matter of the invention is shown in the embodiment example in the drawings, where the individual figures present:

Fig. 1 - presents a kinematic diagram of the device in the upright position,
Fig. 2 - a kinematic diagram of the device while walking,
Fig. 3 - a kinematic diagram of the device in the sitting position,
Fig. 4 - the device in a perspective view in the upright position,
Fig. 5 - the device in a perspective view in the position with the arms parted,
Fig. 6 - the device in a perspective view in the sitting position,
Fig. 7 - the device in a perspective view in the walking position,
Fig. 8 - the foot coupling with the foot support in a perspective view, the device in a perspective view in the upright position,
Fig. 9 - the hip joint articulation with gears in a perspective view.

[0015] The device has a lower limb manipulator comprising two parallel members adjoining the lower limbs of the user. Each of these members consists of a thigh coupling 1, a shin coupling 2 and a foot coupling 3. The thigh coupling 1 and the shin coupling 2 can have their length altered by an adjustable thigh articulation 5 and an adjustable shin articulation 6. The adjustable articulations 5, 6 are interlocked with clamps.

[0016] The foot couplings 3, shin couplings 2 and the thigh couplings 1 connected together in a self-aligning manner in the sagittal plane with pivotal articulations, respectively with ankle joint articulations 11, knee joint articulations 12, and hip joint articulations 13. The ankle joint articulation 11 and the knee joint articulation 12 constitutes the belt rotary gear 21. The hip joint articulation 13 is a backlash-free cycloidal gear 22 connected to the drive 23 with a vibration-dampening belt gear 24 (fig. 4 and fig. 9).

[0017] The device has a stand 8 fitted with vertical guide rails 25 enabling the user to be moved, along with the mechanism members of the manipulator used for moving the lower limbs. The stand 8 design ensures stability in the sagittal plane and in the frontal plane, it is symmetrical with the ability to adjust the lengths of the thigh coupling 1 and the shin coupling 2 to diversified lower limb lengths with interlocked clamps of the adjustable thigh articulations 5 and the adjustable shin articulations 6.

[0018] The stand 8 contains a magnetic barrier 26 in its base, which prevents the foot couplings 3 from hitting the base of the device during its operation.

[0019] The foot couplings 3, the shin couplings 2 and the thigh couplings 1 are suspended in the hip joint articulations 13 and are connected to the lumbar belt 27 with the arms 28 mounted movably in the vertical plane through joint articulations 9 in the guide rails 25. The arms 28 are pivotally mounted on the guide rails 25, with the ability to part sideways, in order to facilitate placing the user on the seat 29. The seat 29, secured on the bracket 15 is movably mounted in the vertical plane through joint articulations 14 on the guide rails 25 (fig. 4).

[0020] The back pusher 10 connected through the lumbar belt 27 with the arms 28 is movable in the vertical plane and sagittal plane.

[0021] The device contains drives 23 of the parallel assemblies of rotary gears of articulations 11, 12, 13 powering the ankle, knee and hip joints. The manipulator mechanisms move in the sagittal plane and actuate the above mentioned drives of the ankle, knee and hip joints of both limbs - linked together with the controller logic and connected with a grip 27 in the lumbar belt. The lumbar belt grip 27 is connected movably in the vertical plane to the stand 8 of the device and is a member that connects the lower limb mechanisms and the stand 8.

[0022] The vertical drive unit 30 enables the user to

move vertically depending on his/her height, the applied lengths of the thigh couplings 1 and the shin couplings 2, and the assumed level of the seat 29. The seat 31 drive unit and the arm 15 of the seat 29 allows buttock support of the user while sitting (fig. 6).

[0023] The drives 23 of the manipulator couplings are servomotors with the system of their precise positioning, including the control systems - reconstructing the correct gait pattern of a healthy human stored in the device controller memory; monitoring systems - inspecting at any time the correctness of the system operation and positioning of the drives in accordance with the stored gait pattern; the protecting system - operating independently and protecting against assuming at any time a position that is at variance with the human anatomy (fig. 7).

[0024] The user can be fastened the device with the thigh cuffs 32 and the shin cuffs 33 of each limb, having the ability to change the position in the frontal and sagittal planes (fig. 6 and fig. 8).

[0025] The fastened user is stabilized by the back pusher 10 and the side hip clamps with a variable position subsequently in the frontal and the sagittal planes.
The fastened user is supported by the foot support 35 with a variable, adjustable position in the side plane, constituting a member of the foot coupling 3.

[0026] The design of the lower limb manipulator is symmetrical and it enables, by lack of contact with the foundation, both walking and moving a lower limb or limbs in any way in accordance with the anatomy to be trained.

Claims

1. Device supporting physical abilities of lower limbs of an user, comprising a stationary non-movable stand (8), a lumbar belt (27), a seat (29), and parallel mobile members adjoining the lower limbs of the user, divided into segments corresponding to the parts of the lower limb of the user and connected with articulations, wherein the lumbar belt (27), movable in the vertical plane, is connected in a hip articulation (13) through arms (28) to mobile couplings of the lower limbs, a back pusher (10) movable in the vertical plane and sagittal plane is connected through the lumbar belt (27) with the arms (28), and the seat (29) movable in the vertical plane is connected to a bracket (15), **characterized in that** the lumbar belt (27), the back pusher (10), the arms (28) and the seat (29) are mounted on common vertical guide rails (25) of the stand (8), the back pusher (10) has a variable position, successively in the frontal plane and in the sagittal plane, whereas the arms (28) are pivotally mounted in the common vertical guide rails (25), movable to part sideways.

2. Device as claimed in claim 1 **characterised in that** it has hip side clamps (34) with a variable position, successively in the frontal plane and the sagittal plane.

3. Device as claimed in claim 1 **characterized in that** each segment of a member that is adjacent to the lower limbs of the user consists of a thigh coupling (1), a shin coupling (2) and a foot coupling (3), in addition the thigh coupling (1) and the shin coupling (2) have a variable, adjustable length through a prismatic articulation interlocked with a clamp and a shin prismatic articulation.

4. Device as claimed in claim 1 **characterised in that** it has a magnetic barrier (26) in the stand base (8).

5. Device as claimed in claim 1 **characterised in that** it has thigh cuffs (32), and shin cuffs (33) that can be shifted in the frontal and sagittal planes.

6. Device as claimed in claim 1 **characterised in that** it has foot supports (35), movable in the frontal and sagittal planes.

7. Device as claimed in claim 1 **characterised in that** an ankle joint articulation (11) has a drive (23) situated on the side plane of the member adjoining the user's limbs.

8. Device as claimed in claim 1 **characterized in that** the ankle joint articulation (11) and a knee joint articulation (12) constitutes a belt rotary gear (21).

9. Device as claimed in claim 1 **characterized in that** a hip joint articulation (13) constitutes a backlash-free cycloidal gear (22) connected to a servomotor with a vibration dampening belt gear (24).

Patentansprüche

1. Vorrichtung zur Unterstützung der motorischen Funktionen der unteren Extremitäten des Benutzers, zusammengesetzt aus stationärem Stativ (8), einem Lendengürtel (27), einer Sitzfläche (29), und parallel zueinander laufenden, sich in unmittelbarer Nähe der unteren Extremitäten des Benutzers befindlichen Elemente, geteilt in Segmente, die den Teilen der unteren Extremität des Benutzers entsprechen und gelenkig angeschlossen sind, in der der Lendengürtel (27), in senkrechter Richtung beweglich, im Hüftgelenk (13) über die Arme (28) mit beweglichen Verbindungstücken der unteren Extremitäten, Rückenschieber (10), in senkrechter und sagittaler Richtung beweglich, über den Lendengürtel (27) mit den Armen (28) verbunden sind, und die Sitzfläche (29), in senkrechter Richtung beweglich, mit einem Halter (15) verbunden ist, **dadurch gekennzeichnet, dass** der Lendengürtel (27), Rückenschieber (10), die Arme (28) und Sitzfläche (29) auf den senk-

rechten gemeinsamen Führungsschienen (25) des Stativs (8) befestigt sind, der Rückenschieber (10) eine veränderliche Lage in axialer, dann sagittaler Richtung hat, und die Arme (28) auf den senkrechten Führungsschienen (25) drehbar befestigt sind, die seitlich gekippt werden können.

2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** sie seitliche Druckplatten in Hüfthöhe (34) mit veränderlicher Lage in axialer, dann in sagittaler Richtung hat.

3. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** jedes Segment des sich in unmittelbarer Nähe der unteren Extremitäten des Benutzers befindlichen Elements aus einem Verbindungselement des Oberschenkels (1), Verbindungselement des Unterschenkels (2), Verbindungselement des Fußes (3) besteht, wobei das Verbindungselement des Oberschenkels (1), Verbindungselement des Unterschenkels (2) eine veränderliche, einstellbare Länge über das mit einer Klemme verriegelte prismatische Gelenk des Oberschenkels und das prismatische Gelenk des Unterschenkels hat.

4. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** sie in der Stativbasis (8) eine magnetische Barriere (26) hat.

5. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** sie die Oberschenkelhalterungen (32) und Unterschenkelhalterungen (33) hat, verschiebbar in axialer und sagittaler Richtung.

6. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** sie die Fußstützen (35) hat, verschiebbar in axialer und sagittaler Richtung.

7. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass sie** das Gelenk des Sprunggelenks (11) einen Antrieb hat (23), der in Längsrichtung des sich in unmittelbarer Nähe der Extremitäten des Benutzers befindlichen Elements befestigt ist.

8. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** das Gelenk des Sprunggelenks (11) und das Gelenk des Kniegelenks (12) ein drehbares Riemengetriebe bilden (21).

9. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** das Gelenk des Hüftgelenks (13) ein spielfreies Zykloidgetriebe (22) bildet, verbunden mit einem Servoantrieb mittels schwingungsdämpfendes Riemengetriebe (24).

Revendications

1. Dispositif de soutien de la capacité de mobilité des membres inférieurs de l'utilisateur, comprenant un trépied immobile fixe (8), une ceinture lombaire (27), un siège (29) et des parties mobiles parallèles entre elles, adjacentes aux membres inférieurs de l'utilisateur, divisées en segments correspondant aux parties des membres inférieurs de l'utilisateur et reliées par des articulations dans lesquelles la ceinture lombaire (27), mobile dans le plan vertical, est reliée dans l'articulation de la hanche (13) à travers les bras (28) avec les connecteurs des membres inférieurs mobiles, le poussoir dorsal (10), mobile dans le plan vertical et le plan sagittal, est relié par la ceinture lombaire (27) avec les bras (28) et le siège (29), mobile dans le plan vertical, est relié au support (15) **caractérisé en ce que** la ceinture lombaire (27), le poussoir dorsal (10), les bras (28) et le siège (29) sont montés sur les guides verticaux communs (25) du trépied (8), le poussoir dorsal (10) a une position variable successivement dans les plans frontal et sagittal, tandis que les bras (28) sont montés sur des guides verticaux articulés (25) en rotation, avec possibilité de s'écarter sur le côté.

2. Dispositif selon la revendication 1, **caractérisé en ce qu'**il présente des pinces iliaques latérales (34) avec une position variable successivement dans le plan frontal et sagittal.

3. Dispositif selon la revendication 1, **caractérisé en ce que** chaque segment de l'élément adjacent aux membres inférieurs de l'utilisateur se compose d'un connecteur de cuisse (1), d'un connecteur de jambe inférieure (2) et d'un connecteur de pied (3), où le connecteur de cuisse (1) et le connecteur de jambe inférieure (2) ont une longueur variable, réglable à travers l'articulation prismatique de la cuisse bloquée et l'articulation prismatique de la jambe inférieure.

4. Dispositif selon la revendication 1, **caractérisé en ce que** la base du trépied (8) a une barrière magnétique (26).

5. Dispositif selon la revendication 1, **caractérisé en ce qu'**il présente des pinces de cuisse (32) et des pinces de jambe inférieures (33) coulissantes dans le plan frontal et sagittal.

6. Dispositif selon la revendication 1, **caractérisé en ce qu'**il présente des supports de pied (35) coulissants dans le plan frontal et sagittal.

7. Dispositif selon la revendication 1, **caractérisé en ce que** l'articulation de la cheville (11) a un entraînement (23) situé sur le plan latéral de l'élément ad-

jacent aux membres de l'utilisateur.

8. Dispositif selon la revendication 1, **caractérisé en ce que** l'articulation de la cheville (11) et l'articulation du genou (12) consistue un engrenage rotatif à courroie (21).

9. Dispositif selon la revendication 1, **caractérisé en ce que** l'articulation de la hanche (13) constitue une transmission cycloïdale sans jeu (22) reliée au servomoteur au moyen d'une transmission à courroie amortissant les vibrations (24).

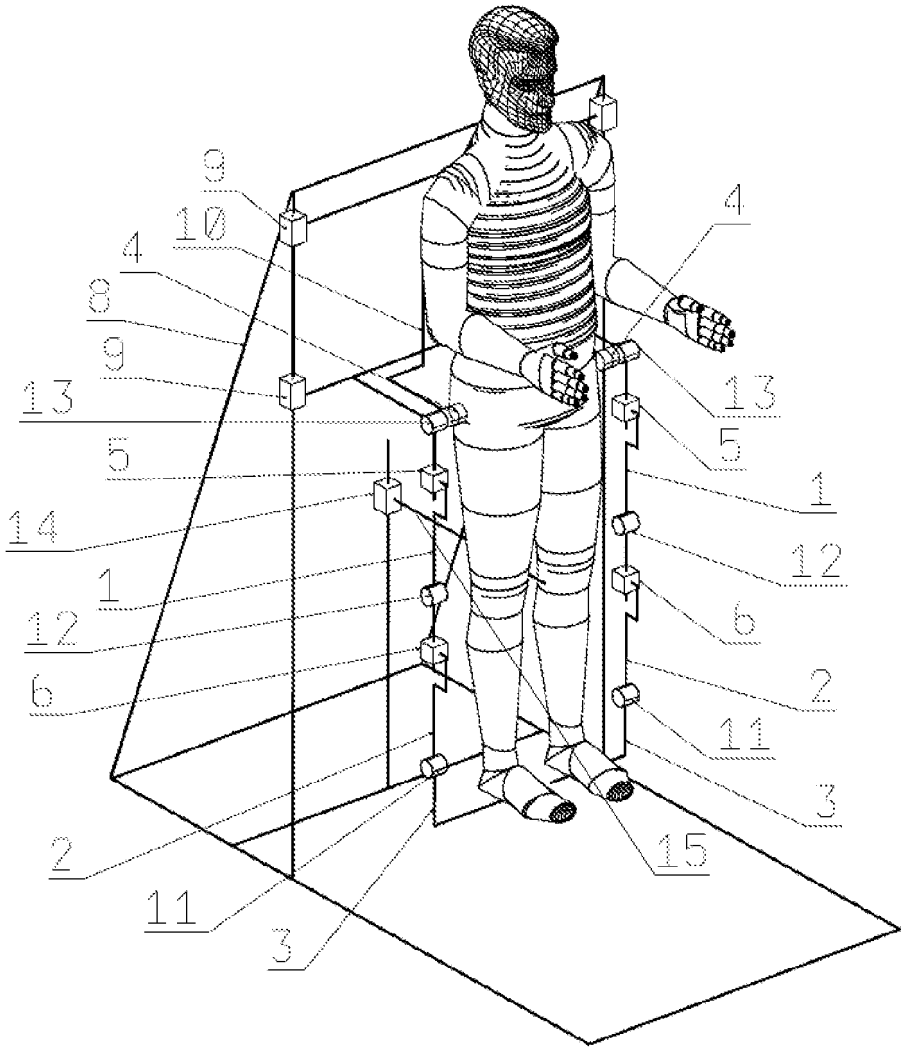


Fig. 1.

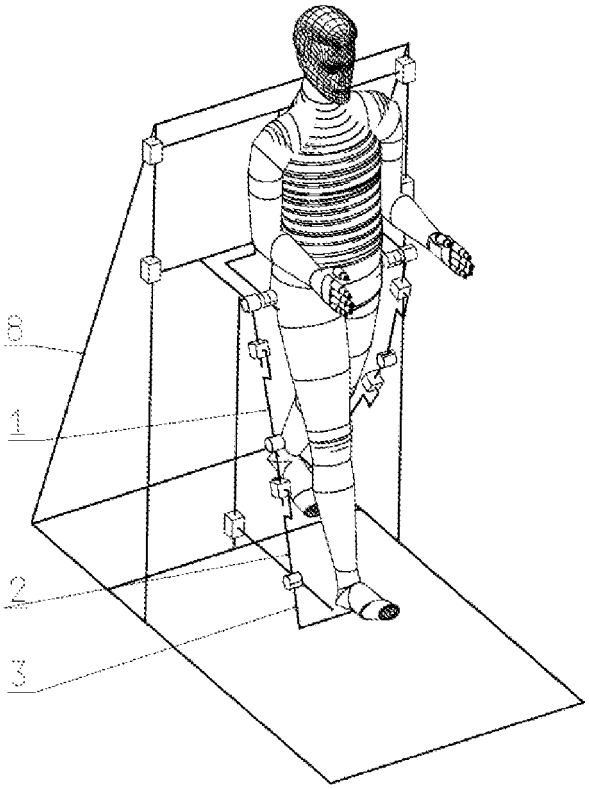


Fig. 2.

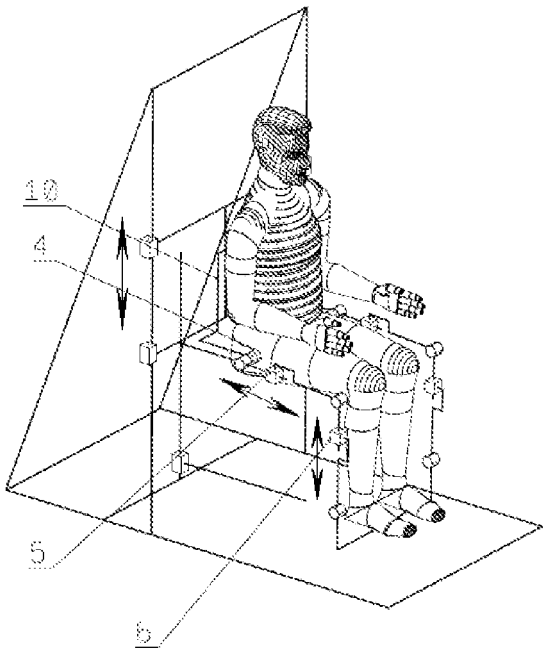


Fig. 3.

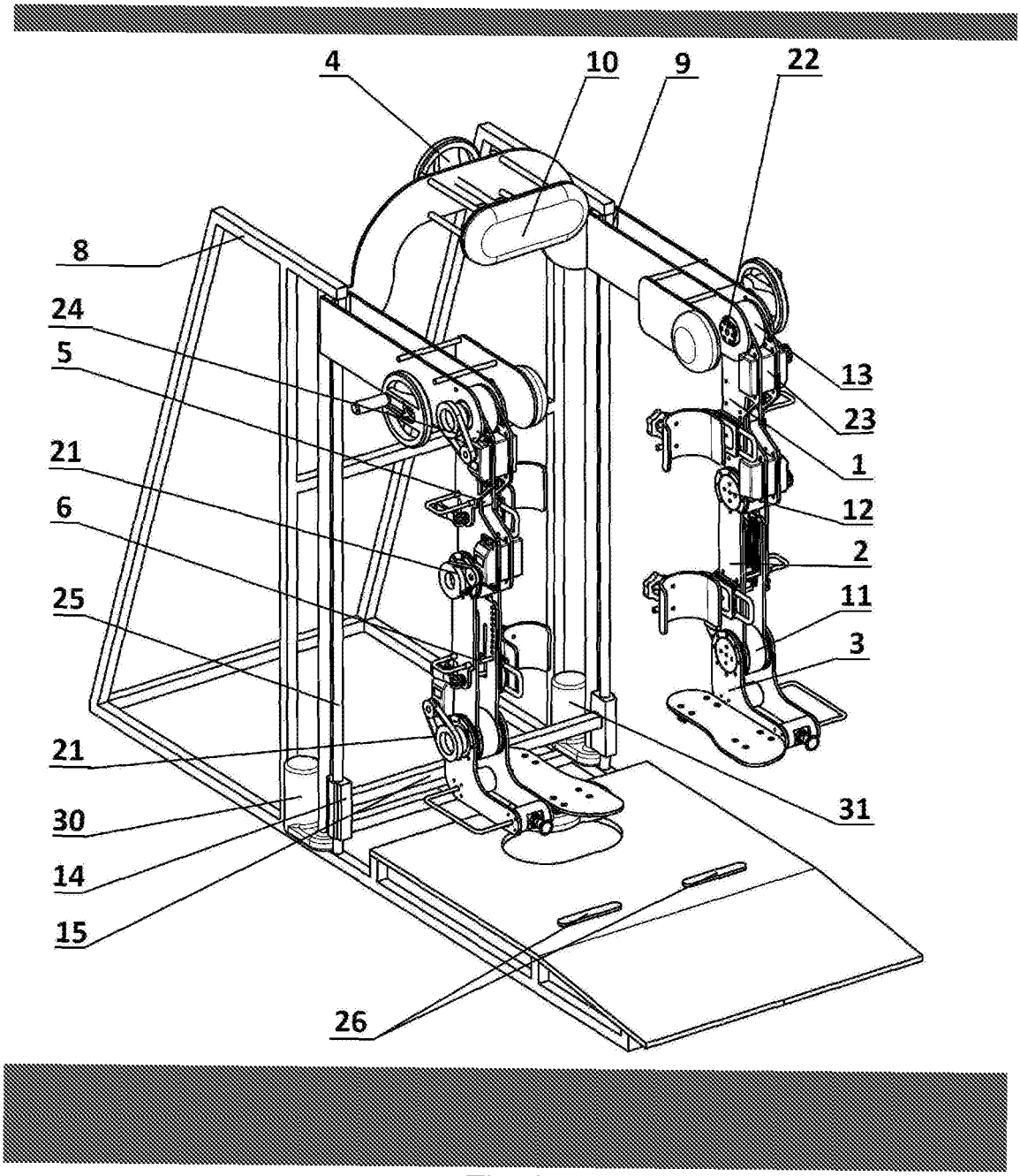


Fig. 4

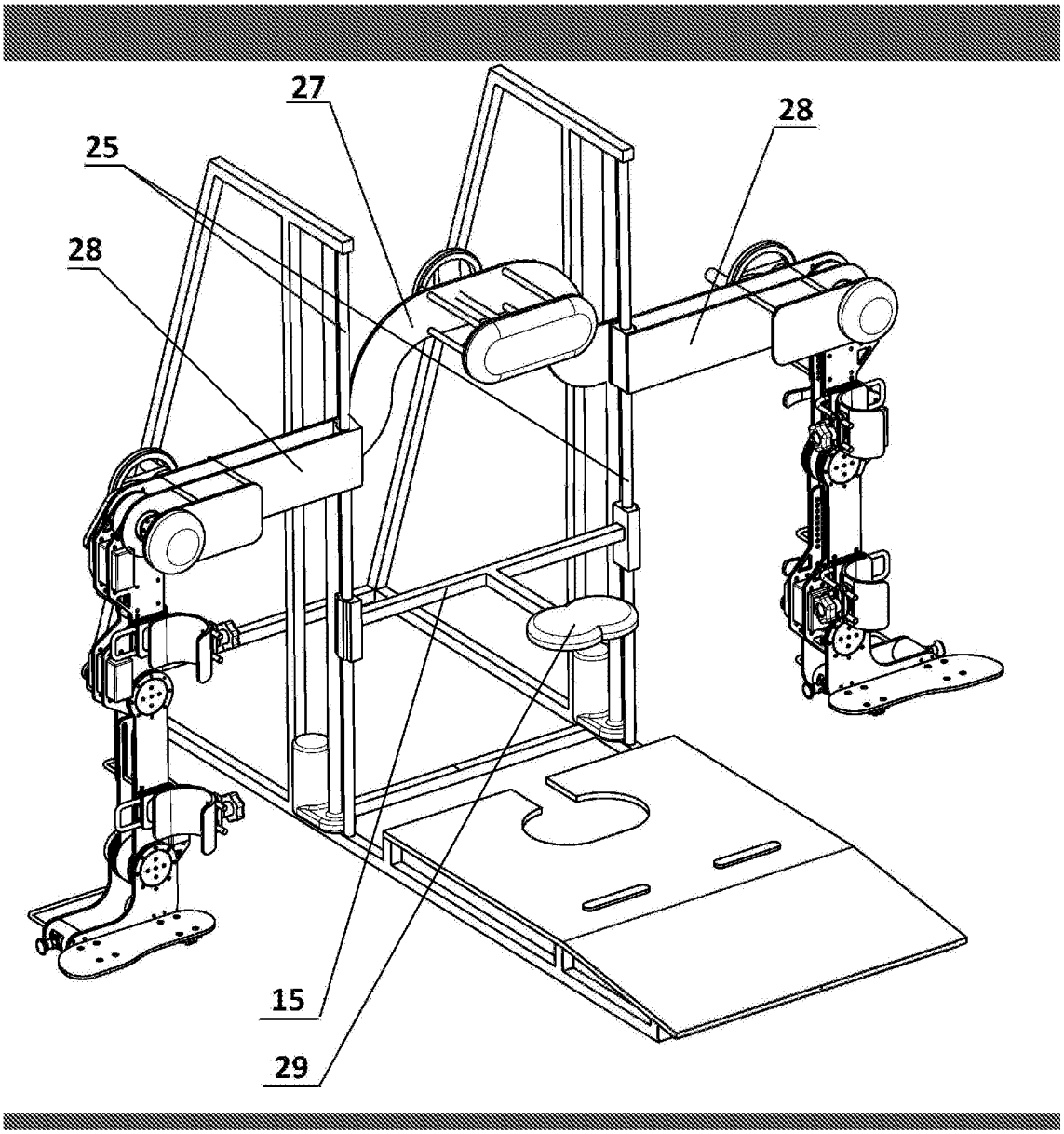


Fig. 5

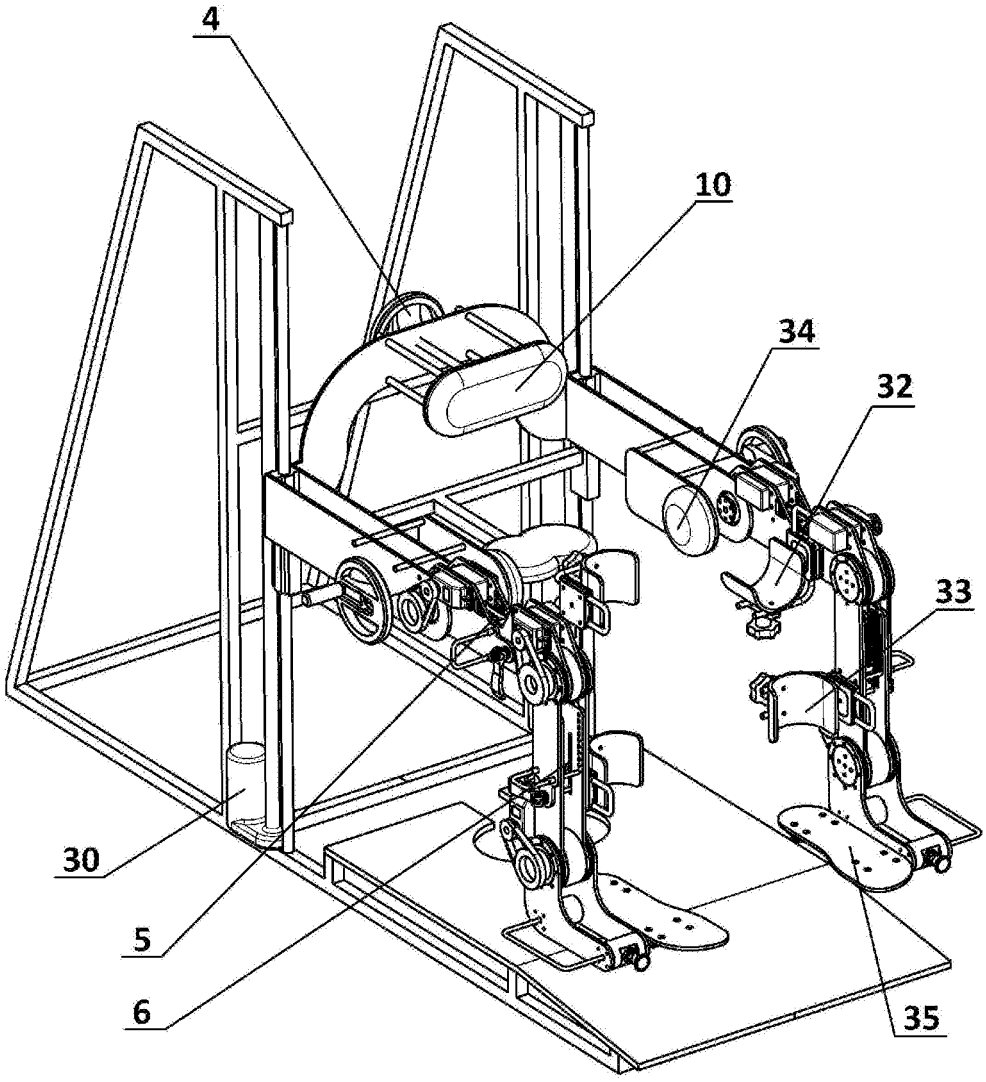


Fig. 6

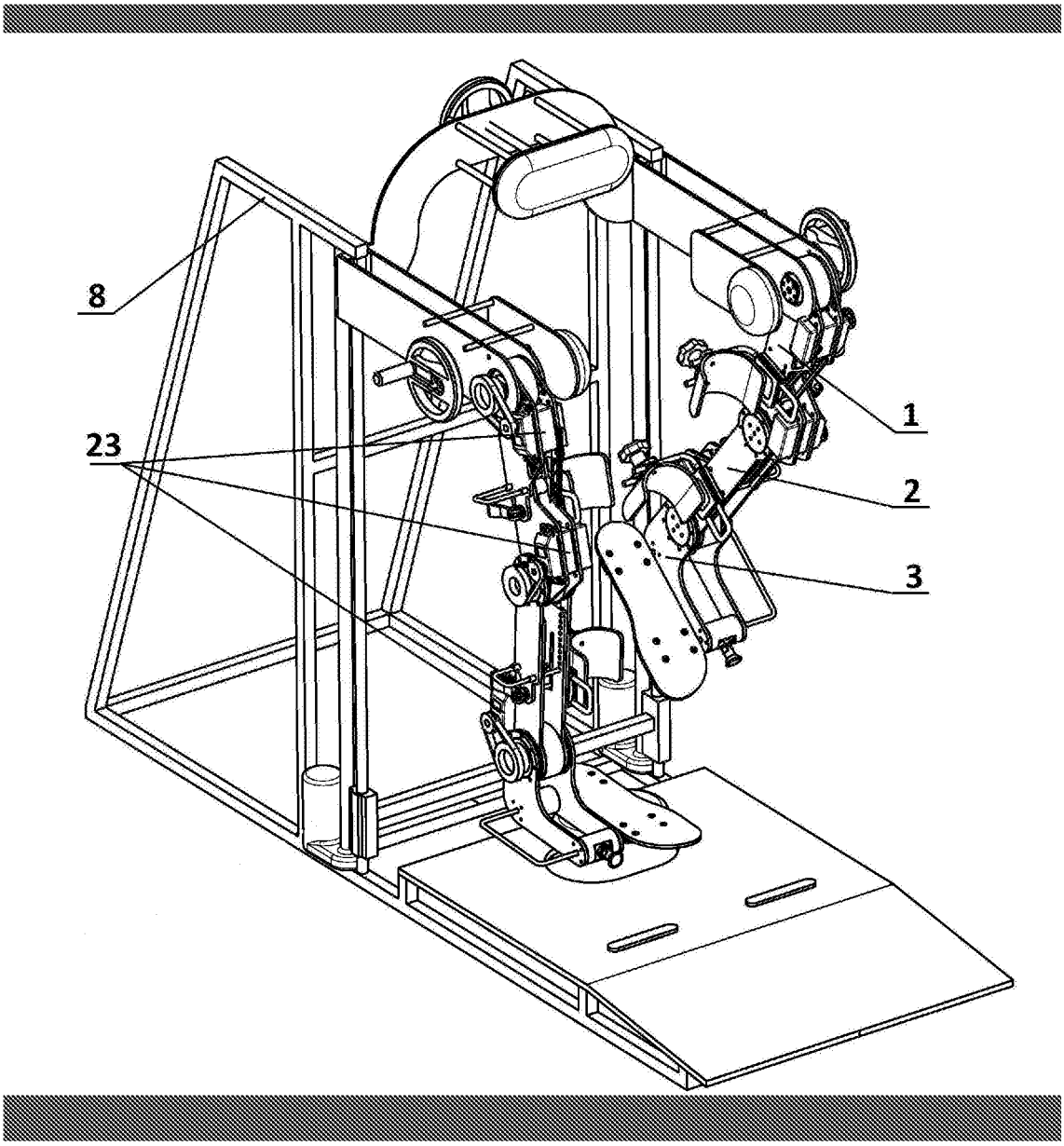


Fig. 7

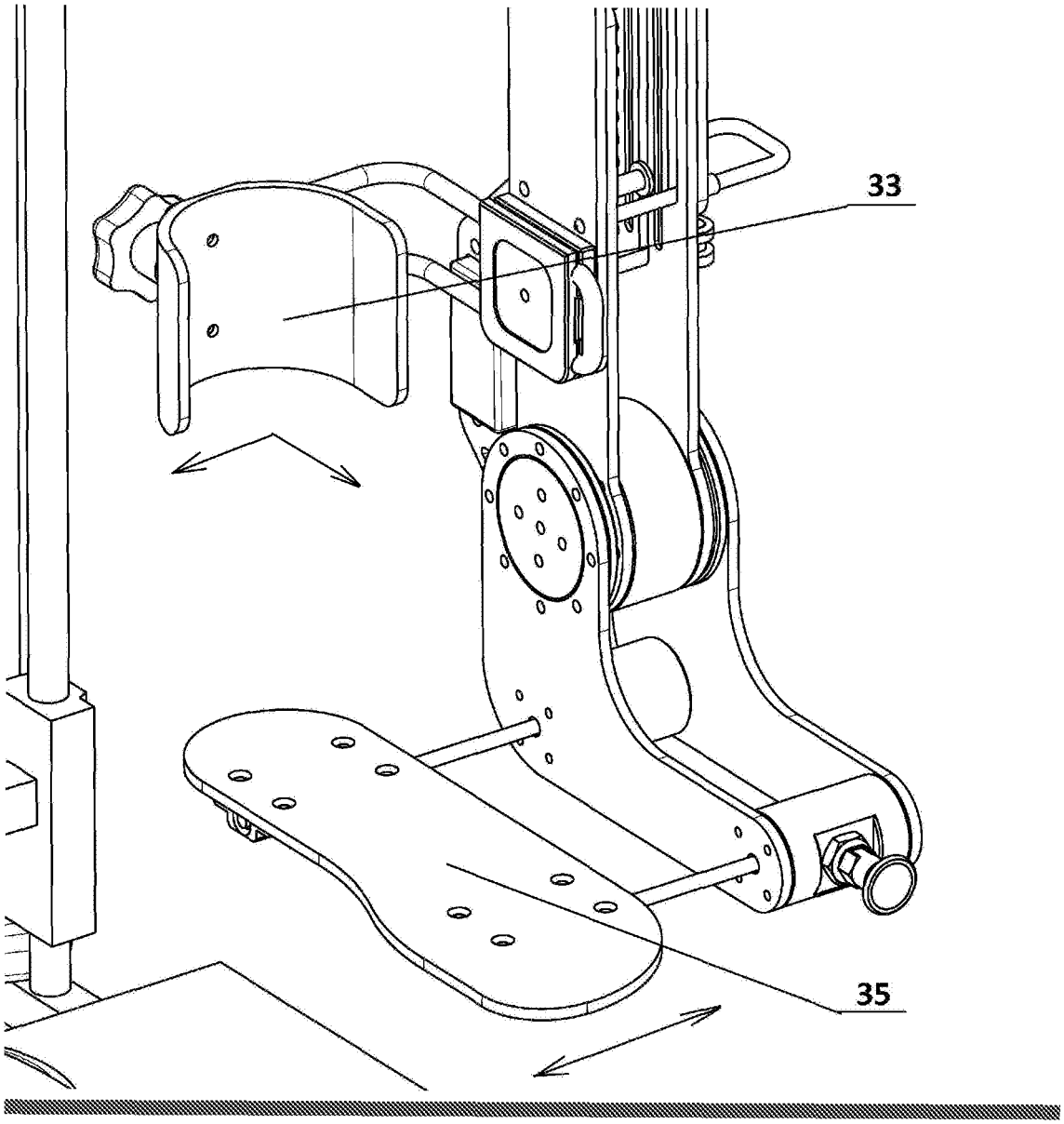


Fig. 8

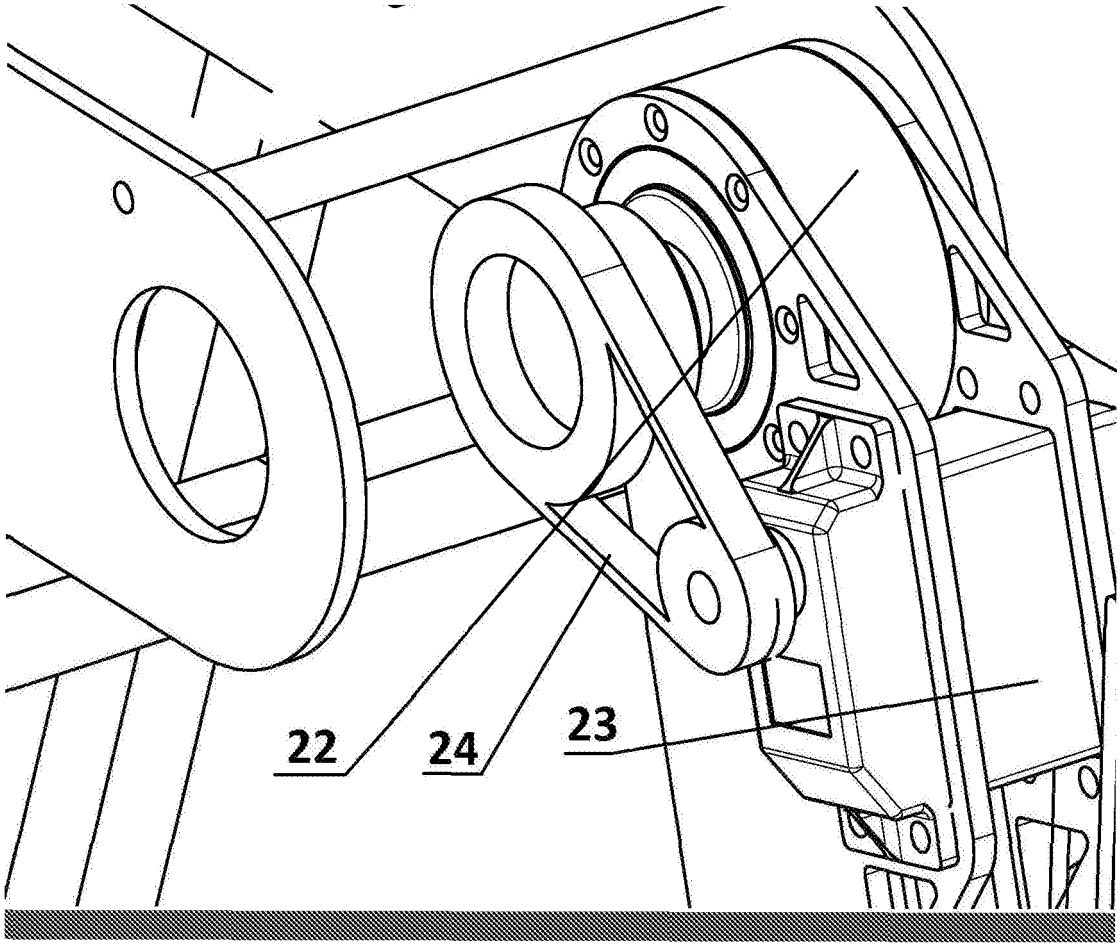


Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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