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[Continued on next page]

(54) Title: PROSTHESIS WITH UNDERACTUATED PROSTHETIC FINGERS

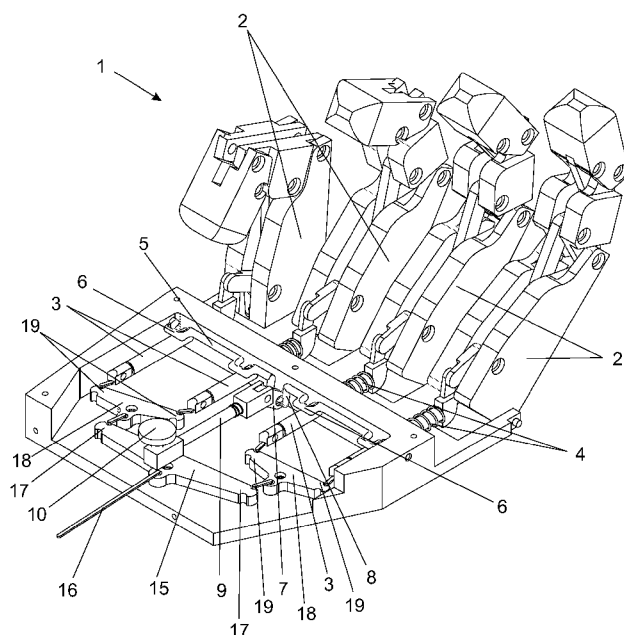


Figure 1

(57) Abstract: An underactuated prosthetic hand is provided in which a plurality of independent finger mechanisms are mechanically movable between open and closed positions by means of longitudinally movable elongate operating elements. The operating elements are at least generally parallel to each other and a releasable locking mechanism is provided for releasably locking the operating elements individually against longitudinal movement in a direction corresponding to opening of the fingers. The finger mechanisms can thus be releasably locked in gripping positions with respect to an object being gripped by the prosthetic hand independently of the relative positions of other finger mechanisms. The releasable locking mechanism is preferably operable to allow movement in a direction corresponding to closing of the finger mechanisms. A connecting mechanism is associated with the longitudinally movable operating elements such that movement of a single main operating member is transferred to all of the finger mechanisms with generally equal force.



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PROSTHESIS WITH UNDERACTUATED PROSTHETIC FINGERS

5 FIELD OF THE INVENTION

This invention relates to prosthesis having underactuated prosthetic fingers that are devoid of complexities such as electric motors, electronic sensors and the like and that relies for its operation entirely on mechanical
10 movement.

In this specification, the term prosthetic hand will be used to refer to the prosthesis of the invention irrespective of the fact that it may be an incomplete prosthetic hand and is described herein without the presence of a
15 thumb and possibly without other components of a complete prosthetic hand.

BACKGROUND TO THE INVENTION

The focus of the prosthetics field has generally shifted from purely
20 mechanical devices to electromechanical devices that employ electrical motors, sensors, circuitry, computer processors and battery power to provide prosthetic devices having great functionality, but at high cost. Much of the amputee market in third world countries is unable to afford such prosthetic devices, even with the assistance of government subsidies.

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Currently available prosthetic hand devices that are accessible to such a market are, as far as applicant is aware, a purely non-functional aesthetic hand or, a metal hook having limited functionality and aesthetic appeal or, a voluntary opening hand with aesthetic appeal but limited functionality. Thus
30 there is a need for a more functional and aesthetically appealing device.

Developments in the area of underactuated mechanical hands include a mechanical finger that was developed by Dechev et al (2001) allowing an anthropomorphic finger to flex in a specific pattern, with slight linear movement at the base of the proximal phalanx. The mechanism is driven by an electric motor and gearbox.

A further underactuation mechanism was developed by Laliberté et al that allowed all fingers to connect and be controlled by a single actuator by way of cables, while still providing the ability to conform to the shape of an object being grasped.

There appears to be considerable scope for improvement in the functionality of such underactuated mechanical hands.

In what follows the term open position in relation to a finger mechanism means a released position in which the finger mechanism is retracted from any object, and the term closed position means a position in which a finger mechanism can exert a grip on an object.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided an underactuated prosthetic hand comprising a plurality of independent finger mechanisms each being mechanically movable between an open and a closed position by means of a longitudinally movable elongate operating element, wherein the operating elements are at least generally parallel to each other; and wherein a releasable locking mechanism is provided for releasably locking the operating elements individually against longitudinal movement in a direction corresponding to opening of the fingers such that the finger mechanisms can be releasably locked in gripping positions with respect to an object being gripped by the prosthetic hand independently of the relative positions of other finger mechanisms.

Further features of the invention provide for the elongate operating elements to be longitudinally movable rods; for there to be four independent finger mechanisms all of which extend approximately parallel to each other in the configuration of a prosthetic hand; and for the finger mechanisms to be
5 biased towards a closed position.

Still further features of the invention provide for the locking mechanism to include a single transverse locking rod extending transverse to the operating elements and being rotatable about an axis extending along the length of the
10 transverse locking rod between a locked position in which axially eccentric locking surfaces cooperate with each of the operating elements and an unlocked position in which the locking surfaces are disengaged from the operating elements; for the arrangement of the locking surfaces to be such that engagement thereof with a cooperating locking element is arranged to
15 increase the locking force with increased force placed on the associated finger mechanism in a direction corresponding to opening of that finger mechanism; for the releasable locking mechanism to be manually engageable or disengageable, or both, according to design requirements; and for the locking mechanism to have a manually engageable operating button
20 preferably located approximately in the position of the heel or palm area of the prosthetic hand that is at least functional to release the locking mechanism.

In a first variation of the invention the releasable locking mechanism may be
25 biased to a position in which it is engaged with the cooperating longitudinally movable operating elements to allow movement thereof in a direction corresponding to closing of the associated finger mechanism in which instance a manually operable release mechanism is provided for releasing a grip exerted by the finger mechanisms on an object.

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In a second variation of the invention the releasable locking mechanism is arranged to be manually moved to a locked position in order to releasably

lock the longitudinally movable operating elements against movement in a direction corresponding to opening of the finger mechanisms.

Movement of the longitudinally movable operating elements may be achieved
5 in any suitable manner and, in particular, utilising a suitable connecting mechanism associated with the longitudinally movable operating elements such that movement of a single main operating member is transferred to all of the finger mechanisms with generally equal force. The interconnecting mechanism therefore serves to distribute force exerted on the single main
10 operating member generally equally between the finger mechanisms such that each of the finger mechanisms exerts approximately the same force on any object being clasped irrespective of the degree to which the finger mechanism is closed when it engages the object.

15 One simple form of such a mechanism is a system of levers that comprises a first lever to the centre of which is attached a main operating member, typically a cable, and to the ends of which are attached the centres of second and third levers the free ends of which are in turn attached to the individual longitudinally movable operating elements. In this way the force exerted by
20 the main operating member is distributed substantially equally between the four longitudinally movable operating elements.

The main operating member may be moved using any suitable movement generating arrangement but it is considered to be especially suitable for
25 movement by means of a shoulder harness of well-known type. Alternatively, in a more sophisticated version, a pneumatically or electrically driven apparatus may move the main operating member.

As regards the mechanics of the finger mechanisms, these may assume any
30 suitable form and may be either lever or cable operated. One form of finger mechanism that is considered to be especially suitable is a lever operated underactuated finger mechanism of the general type described in an article

entitled "MULTIPLE FINGER, PASSIVE ADAPTIVE GRASP PROSTHETIC HAND" by N Dechev et al and published in the publication MECHANISM AND MACHINE THEORY 36 (2001) 1157-1173 by Pergamon press (Elsevier). The description contained in that article is incorporated herein to
5 the extent that it is necessary for a complete understanding of the present invention.

As regards the mechanics of a system of levers, an article entitled "TOWARDS THE DESIGN OF A PROSTHETIC UNDERACTUATED HAND"
10 by T. Laliberté, M. Baril, F. Guay, and C. Gosselin and published in the journal Mechanical Sciences 1 (2010) 19-26 by Copernicus Publications describes a suitable system. That disclosure is incorporated herein by reference to the extent that it is necessary for a complete understanding of the present invention.

15

In order that the invention may be more fully understood, one embodiment thereof will now be described with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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In the drawings:-

Figure 1 is a perspective view of the mechanism of one embodiment of prosthetic hand according to the invention with cover
25 plates removed;

Figure 2 is a reduced size of the same view but with the main cover plate in position;

30 Figure 3 is a sectional view of an operating rod and transverse locking rod and mechanism of the prosthetic hand with the locking mechanism in an unlocked position;

Figure 4 is the same as Figure 3 but illustrating the locking mechanism in a locked position;

5 Figure 5 is an enlarged sectional view of the central two operating rods showing the eccentric locking cranks in their disengaged positions;

Figure 6 is the same as Figure 5 but showing the eccentric locking cranks in their engaged positions; and,

10

Figure 7 is a plan view of the prosthetic hand with the cover plates removed and illustrating more clearly the force transmitting mechanism connecting the individual operating rods with a main operating member.

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DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

In the embodiment of the invention illustrated in the drawings, an underactuated prosthetic hand, generally indicated by numeral (1), comprises
20 four independently operable finger mechanisms (2) each of which is mechanically movable between an open and a closed position by means of a longitudinally movable elongate operating element in the form of an axially movable operating rod (3). The arrangement is such that movement of an operating rod axially towards its associated finger mechanism causes
25 opening of the finger mechanism whilst movement of the operating rod in the opposite direction, namely away from the finger mechanism, causes the finger mechanism to close. In one preferred arrangement, the operating rods are biased by means of compression springs (4) toward a position corresponding to an open position of the relevant finger mechanism.

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In this embodiment of the invention the finger mechanisms are lever based and are constructed along the lines described in the article of N Dechev et al

identified above and a further description of which is not relevant to an understanding of the present invention. However, reference may be had to that article in the event that the finger mechanisms are to be replicated.

- 5 The four operating rods are generally parallel to each other and are spaced apart laterally in accordance with the spacing of the four finger mechanisms so that each operating rod extends roughly centrally to the base of the relevant finger mechanism. A releasable locking mechanism in the form of a single transverse locking rod (5) is provided extending transverse to the
10 operating rods and is rotatable about an axis extending generally along the length of the transverse locking rod. The transverse locking rod can thus be rotated between an unlocked position that is illustrated particularly in Figures 3 and 5 in which locking surfaces on crank formations (6) are disengaged from the operating rods, and a locked position that is illustrated particularly
15 Figures 4 and 6 in which the locking surfaces on the crank formations engage each of the operating elements.

It will be understood that the operating rods are individually locked against longitudinal movement in a direction corresponding to opening of the fingers
20 so that the finger mechanisms can be releasably locked in gripping positions with respect to an object being gripped by the prosthetic hand independently of the relative positions of other finger mechanisms.

The crank formations and transverse locking rod are arranged such that
25 engagement of a crank formation with a cooperating operating rod is arranged to increase the locking force with increased force placed on the associated finger mechanism in a direction corresponding to opening of that finger mechanism.

- 30 Rotation of the transverse locking rod is effected by way of a link (7) pivotally attached to a central radially extending operating crank (8) rotatable in unison with the transverse locking rod and a manually axially slidable control rod (9)

having a finger operable button (10) at its opposite end. The button is located approximately in the position of the heel or palm area of the prosthetic hand.

5 In a first variation of the invention the manually axially slidable control rod (9) is biased by means of a compression spring (12) (see Figures 3 and 4) to a position in which the crank formations are engaged with the cooperating longitudinally movable operating rods to allow movement thereof only in a direction corresponding to closing of the associated finger mechanism. In
10 that instance the finger operable button may be used to release a grip exerted by the finger mechanisms on an object. In this instance a slot in the cover plate in which a connecting rod for the finger operable button is slidable may have a lateral notch (11) (see Figure 2) in order to provide a locked position with the compression spring in a compressed state.

15 In a second variation of the invention the compression spring (12) is omitted and the manually axially slidable control rod (9) is arranged to be moved manually to a locked position in order to releasably lock the longitudinally movable operating elements against movement in a direction corresponding
20 to opening of the finger mechanisms. In such an instance unlocking of the transverse locking rod is achieved by moving the control rod (9) in the opposite direction.

Movement of the longitudinally movable operating rods is achieved, in this
25 embodiment of the invention, by means of a suitable connecting mechanism in the form of a system of levers that, as shown clearly in Figure 7, comprises a first lever (15) to the centre of which is attached a main operating member in the form of a cable (16). The ends (17) of the first lever are attached to the centres of second and third levers (18) the free ends (19) of which are in turn
30 attached to the four individual longitudinally movable operating rods. In this way the force exerted by the cable is distributed substantially equally

between the four longitudinally movable operating rods and thus the four finger mechanisms.

As mentioned above, the cable may be moved using any suitable movement
5 generating arrangement that, for present purposes, is intended to be a shoulder harness of well-known type and that is not further discussed or illustrated herein.

It will be understood that whatever the variation of the invention that is
10 employed, the lock on the operating rods, once it is engaged, is automatically reinforced by any attempt to open a finger mechanism, due to the angle between the relevant crank formation on the transverse locking rod and the operating rod engaged by it. If there is an opening force applied to a finger
15 mechanism, the relevant operating rod will be urged to move longitudinally which in turn will enhance the friction between the crank formation and the operating rod. This, in turn, would attempt to rotate the transverse locking rod thereby reinforcing the lock.

The mechanism will lock each finger mechanism individually in its then
20 current position that would generally be in engagement with an object being gripped with no dependence on the positions of the other finger mechanisms. This removes the need for any finger closing force to be exerted on the operating rods thereby allowing a user to relax whilst maintaining a firm grip on the relevant object being held in the prosthetic hand.

25

The prosthetic hand of the invention thus allows the fingers of the artificial hand to be simultaneously locked in an existing position, either automatically or by pushing a single sliding button located on the palm of the hand.

30 Numerous variations may be made to the embodiment of the invention described above without departing from the scope hereof. In particular, the nature of the finger mechanisms can be varied widely. Also, the nature of the

longitudinally movable operating elements may vary from the operating rods described above. The mechanism for distributing force applied by a main operating member may also be varied. Still further, the mechanical detail of the locking mechanism can be varied widely.

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CLAIMS:

1. An underactuated prosthetic hand comprising a plurality of independent finger mechanisms each being mechanically movable between an open
5 and a closed position by means of a longitudinally movable elongate operating element, wherein the operating elements are at least generally parallel to each other; and wherein a releasable locking mechanism is provided for releasably locking the operating elements individually against longitudinal movement in a direction corresponding
10 to opening of the fingers such that the finger mechanisms can be releasably locked in gripping positions with respect to an object being gripped by the prosthetic hand independently of the relative positions of other finger mechanisms.
- 15 2. An underactuated prosthetic hand as claimed in claim 1 in which the elongate operating elements are longitudinally movable rods.
3. An underactuated prosthetic hand as claimed in either one of claims 1
20 or 2 in which there are four independent finger mechanisms all of which extend approximately parallel to each other in the configuration of a prosthetic hand.
4. An underactuated prosthetic hand as claimed in any one of the
25 preceding claims in which the finger mechanisms are biased towards a closed position.
5. An underactuated prosthetic hand as claimed in any one of the
30 preceding claims in which the locking mechanism includes a single transverse locking rod extending transverse to the operating elements and being rotatable about an axis extending along the length of the transverse locking rod between a locked position in which axially eccentric locking surfaces cooperate with each of the operating

elements and an unlocked position in which the locking surfaces are disengaged from the operating elements.

- 5 6. An underactuated prosthetic hand as claimed in claim 5 in which the arrangement of the locking surfaces is such that engagement thereof with a cooperating locking element is arranged to increase the locking force with increased force placed on the associated finger mechanism in a direction corresponding to opening of that finger mechanism.
- 10 7. An underactuated prosthetic hand as claimed in any one of the preceding claims in which the releasable locking mechanism is manually engageable or disengageable, or both.
- 15 8. An underactuated prosthetic hand as claimed in any one of the preceding claims in which the releasable locking mechanism has a manually engageable operating button.
- 20 9. An underactuated prosthetic hand as claimed in any one of the preceding claims in which the releasable locking mechanism is biased to a position in which it is engaged with the cooperating longitudinally movable operating elements to allow movement thereof in a direction corresponding to closing of the associated finger mechanism in which instance a manually operable release mechanism is provided for releasing a grip exerted by the finger mechanisms on an object.
- 25 10. An underactuated prosthetic hand as claimed in any one of claims 1 to 8 in which the releasable locking mechanism is arranged to be manually moved to a locked position in order to releasably lock the longitudinally movable operating elements against movement in a direction corresponding to opening of the finger mechanisms.
- 30

11. An underactuated prosthetic hand as claimed in any one of the preceding claims in which a connecting mechanism is associated with the longitudinally movable operating elements such that movement of a single main operating member is transferred to all of the finger mechanisms with generally equal force.
12. An underactuated prosthetic hand as claimed in claim 11 in which the connecting mechanism comprises a first lever to the centre of which is attached a main operating member and to the ends of which are attached the centres of second and third levers the free ends of which are in turn attached to the individual longitudinally movable operating elements.
13. An underactuated prosthetic hand as claimed in either one of claims 11 or 12 in which the main operating member is configured to be movable using a shoulder harness.

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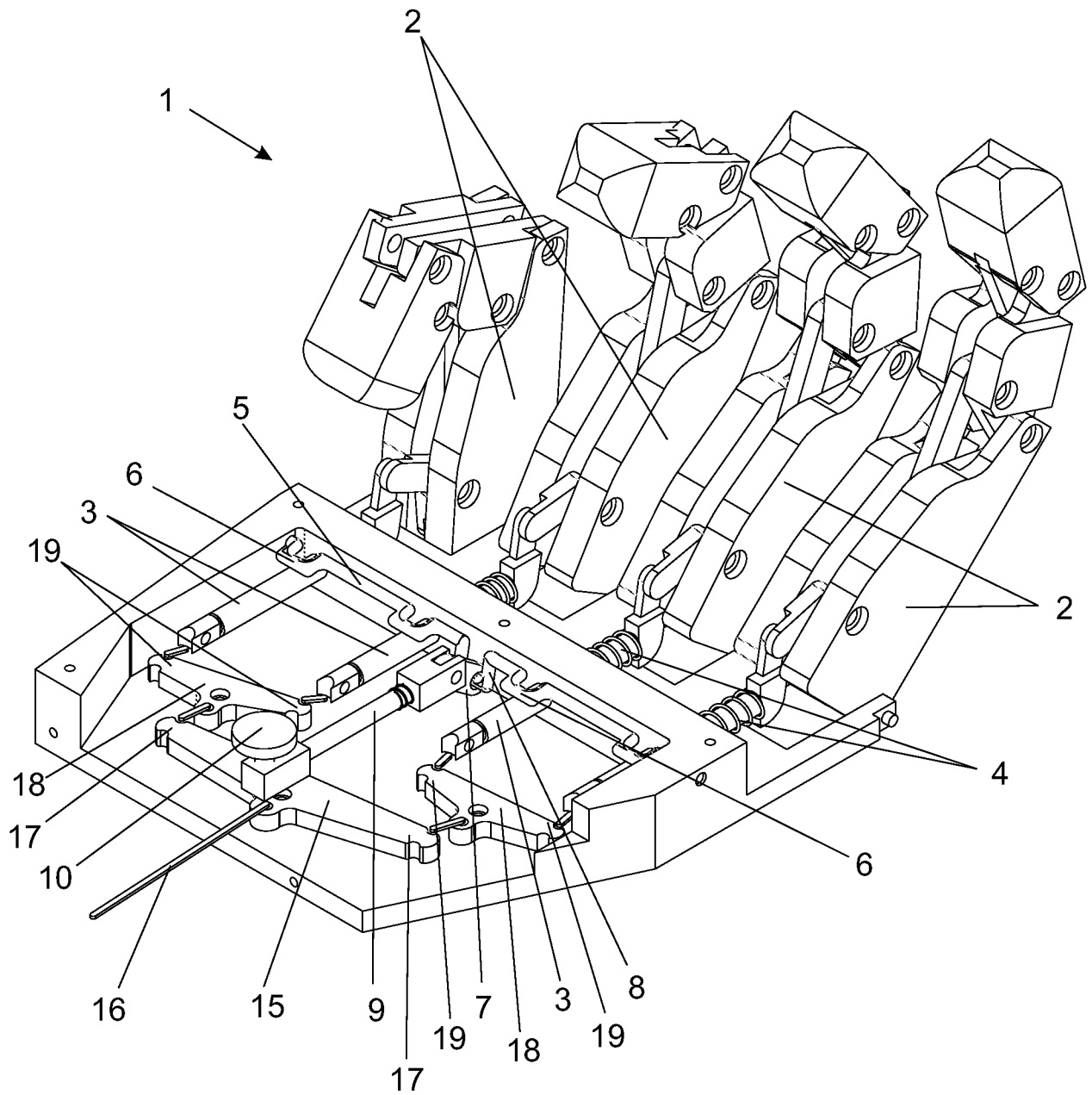


Figure 1

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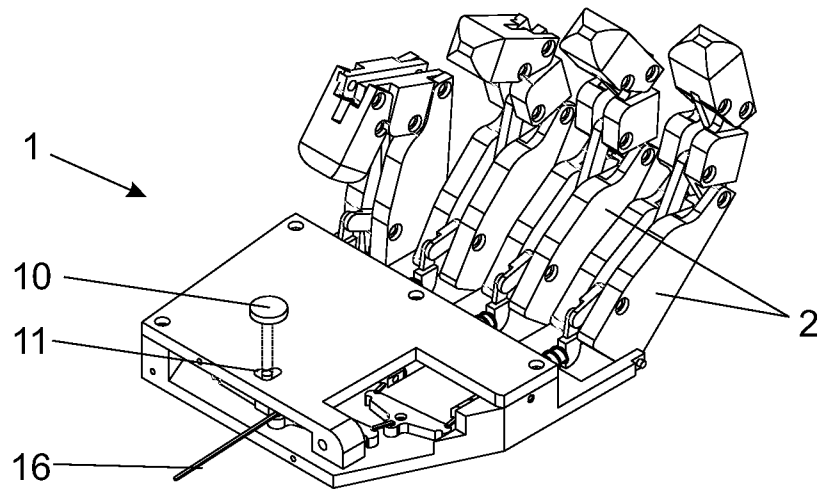


Figure 2

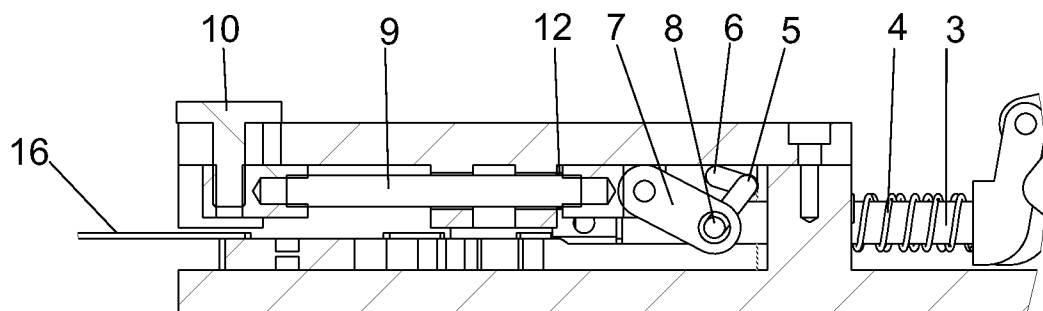


Figure 3

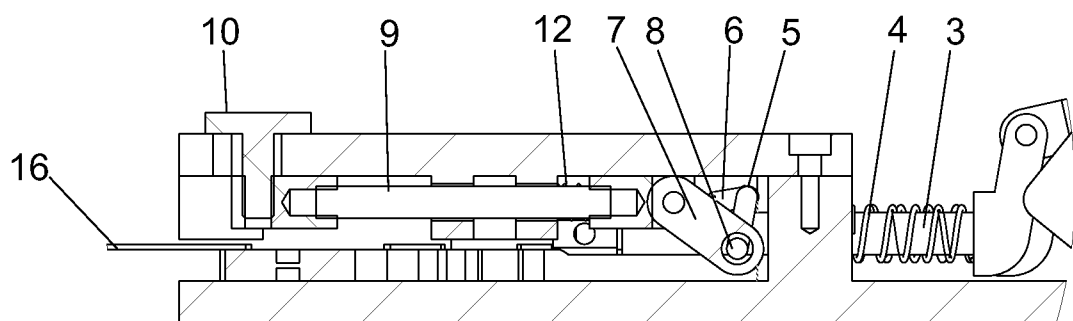


Figure 4

3 / 4

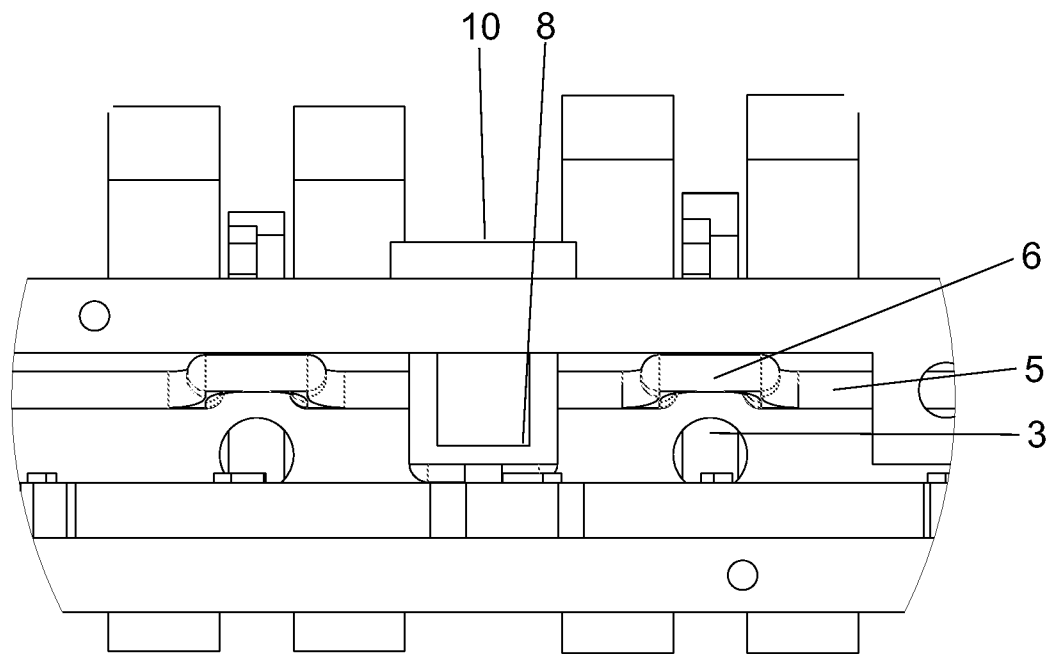


Figure 5

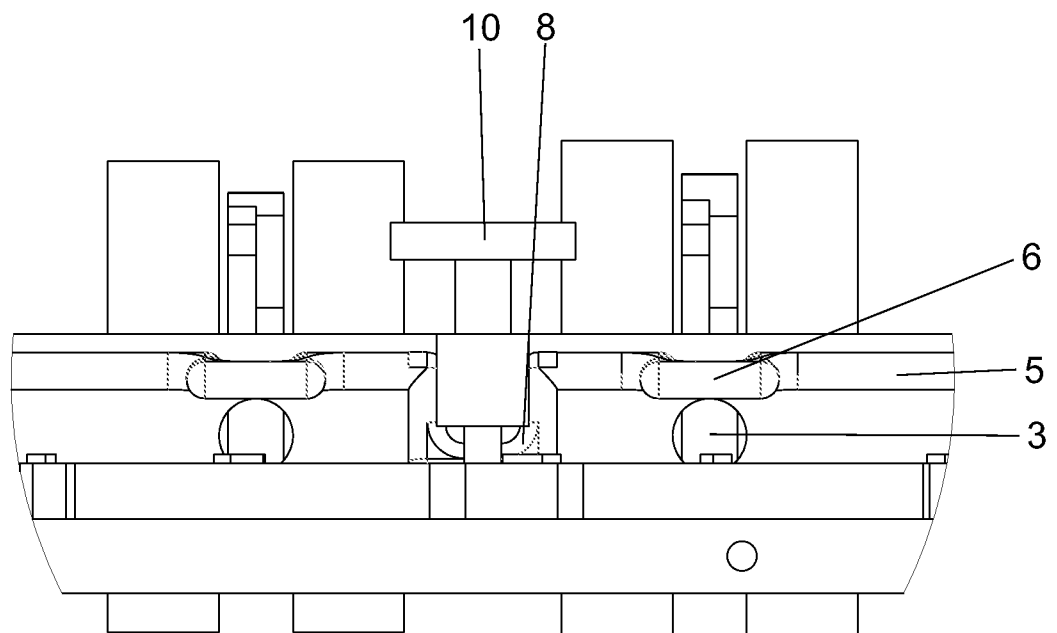


Figure 6

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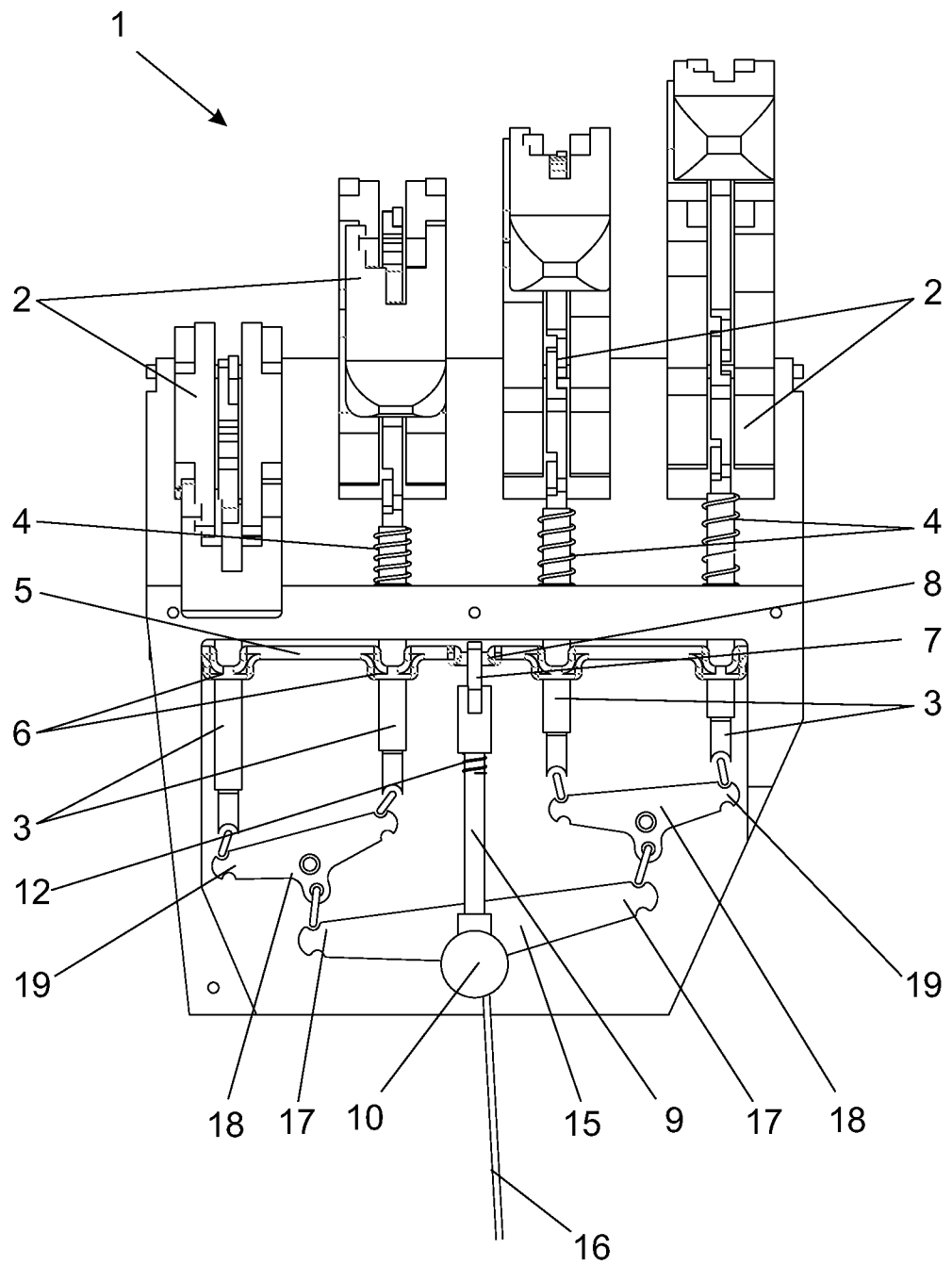


Figure 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2012/056637

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61F2/58

ADD. A61F2/50 A61F2/68

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 B25J

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 1 507 680 A (ALBERTO PECORELLA ET AL) 9 September 1924 (1924-09-09)	1-4,7,9, 10,13
Y	page 1, line 14 - page 3, line 86; figures 1-3	11,12
X	FR 2 822 404 A1 (LOPEZ GILLES [FR]) 27 September 2002 (2002-09-27)	1-4,7-9, 13
X	DE 197 55 465 A1 (DECHERT ALEXANDER [DE]) 17 June 1999 (1999-06-17)	1,3,4, 6-11,13
Y	column 1, line 48 - column 3, line 46; figures 1,2,12	11
Y	GB 237 085 A (LIVINGSTON ARTIFICIAL LIMB COM) 23 July 1925 (1925-07-23)	11,12
	page 3, lines 77-117; figure 11	
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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Date of mailing of the international search report

25/03/2013

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INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2012/056637

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 685 929 A (MONESTIER JACQUES [FR]) 11 August 1987 (1987-08-11) column 5, lines 20-44; figure 2 -----	11,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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