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(54) Title: UNDERACTUATED PROSTHETIC HAND

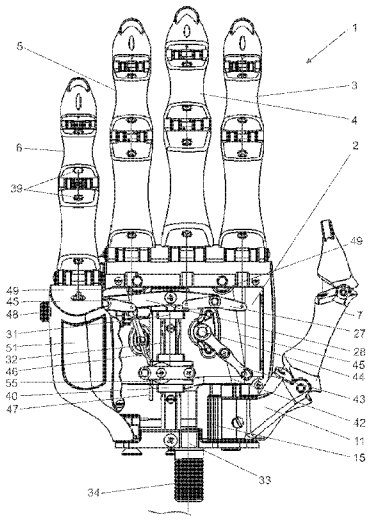


Figure 9

(57) Abstract: An underactuated prosthetic hand (1) is provided having a plurality of independent finger mechanisms extending from a metacarpal part (2) of the hand, the mechanisms being mechanically movable between open position and closed positions by means of tension elements (25) interconnected by means of levers (27). The levers are operable by a single operating tension element (33) that also operates a thumb mechanism (7) attached to one side of the metacarpal part of the hand. The thumb mechanism is mechanically movable between open position and closed position by means of a tension element (42). The thumb has a thumb swivel element (11) that is manually rotatable between positions in which the thumb is in an adducted lateral grasp terminal position and an abducted power grasp terminal position. A single operating tension element is connected to a longitudinally movable operating carriage (40) associated with operation of the thumb mechanism and a longitudinally movable lever carriage (31) associated with the finger mechanisms.

UNDERACTUATED PROSTHETIC HAND

CROSS-REFERENCE(S) TO RELATED APPLICATIONS

This application claims priority to United Kingdom patent application number GB1412034.9, which is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates to an underactuated prosthetic hand having a functional thumb and that may optionally be devoid of complexities such as electric motors, electronic sensors and the like. The underactuated prosthetic hand of this invention may therefore rely for its operation entirely on mechanical movement although electric motors may be used in more advanced versions.

BACKGROUND TO THE INVENTION

The focus of modern commercial upper limb prosthetic development has generally shifted from purely mechanical devices to electromechanical / myoelectric devices that employ electric motors, sensors, circuitry, computer processors and battery power. These myoelectric prosthetic devices offer improved functionality and usability, as actuation is achieved through an electric motor, reducing the workload for the user. Unfortunately, these devices are expensive and many amputees in third world countries are unable to afford them, even with assistance of a government subsidy or a medical aid, or both.

In many of such countries affordable prosthetic devices include a passive/cosmetic hand; a cable-driven metal hook; and a voluntary-opening claw. The passive hand, while aesthetically appealing, is non-functional; the hook has increased functionality but is aesthetically unappealing; and the voluntary opening claw is aesthetically appealing but has limited functionality. Furthermore, these purely mechanical devices are often undesirable as an operating cable mechanism which promotes their movement may require a large amount of effort to actuate the device. This may fatigue or frustrate a user of such a device.

Thus there is a need for a more functional and aesthetically appealing device at a more affordable price than the rather sophisticated computer controlled prosthetic hands.

The prior art revolving around the invention of prosthetic hand devices is extensive covering many different types of body-powered and externally powered prostheses. Attention will only be paid herein to those of which the applicant is aware and to those which relate to the subject matter of this invention, and whose mechanisms are of relevance.

United States patent number US4685929 to Monestier describes a hand prosthesis with four moveable fingers and a detachable, yet rigid thumb. The fingers used are cable actuated and have a return spring mechanism used to extend the digits to their open position. The device uses a force balancer to provide independent motion between fingers and a single compression spring to overcome friction of the single traction cable and to return the digits to their open positions. Moreover, an eccentric friction-based locking mechanism is employed. The main asymmetric balancer arm in the design of Monestier is floating.

United States patent number US4246661 to Pinson describes a digitally controlled artificial arm which claims to reproduce human arm and hand motions through the use of an inline, compact, lightweight and cosmetically pleasing device, using seven stepper motors for actuation. Finger underactuation is achieved using cables which pass over pulleys in the hinge-joint and are coupled directly to the stepper motors in a cylindrical forearm portion of the unit. The unit uses linear springs to open the hand. This patent may be of relevance when the placement of external actuation units in future variations of the present invention within a prosthetic socket or sleeve that attaches to the patient.

A further underactuated mechanism is described by Laliberté et al. in an article in Mech. Sci., 1, 19–26, 2010 wherein all fingers connect to, and are controlled by a single actuator, by way of cables, and thereby providing the ability to conform to the shape of an object being grasped. Laliberté et al. describe a thumb that can be rotated between a terminal position appropriate to a lateral pinch grasp and a terminal position appropriate to a pinch grasp or enveloping grasp. The mechanism that moves the artificial phalanges of the thumb includes two operating cables, one for opening the thumb and one for closing it. This complicates the operation of the hand and the thumb needs to be manually rotated to its selected terminal position from a home position. The home position is mentioned as preferably being the lateral position.

There is considerable scope for improvement in the functionality of such underactuated mechanical hands.

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

an object.

Also, in order to facilitate an understanding of the invention, the artificial components of each prosthetic hand or digit may be referred to by the anatomical names of the equivalent parts of the human body irrespective of the fact that they are substitutes for the original human anatomical parts.

A hand for the purposes of this specification can conveniently be considered to include a metacarpal part having an inner palmar surface and an outer dorsal surface with four finger digits projecting from one of its end regions and a thumb digit attached to one side of the metacarpal part selected according to whether the hand is a left or right hand.

The preceding discussion of the background to the invention is intended only to facilitate an understanding of the present invention. It should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was part of the common general knowledge in the art as at the priority date of the application.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided an underactuated prosthetic hand comprising a plurality of independent finger mechanisms extending from a metacarpal part of the hand whereof at least selected finger mechanisms are mechanically movable between an open position and a closed position by means of a finger operating mechanism that includes tension elements that are interconnected by means of levers so as to be operable by a single operating tension element, and a thumb mechanism attached to one side of the metacarpal part of the hand with the thumb mechanism also being mechanically movable between an open position and a closed position by means of a thumb operating mechanism that includes a tension element; wherein the thumb is attached to the metacarpal part of the hand by way of a thumb swivel element that is rotatable about an axis extending in a direction that is the same as that in which the finger and thumb mechanisms extend such that the thumb swivel element is rotatable between positions in which the thumb is in an adducted lateral grasp terminal position and an abducted power grasp terminal position, the underactuated prosthetic hand being characterized in that a single operating tension element is connected to a longitudinally movable operating carriage associated with operation of the thumb mechanism and a longitudinally movable lever carriage is associated with the finger mechanisms wherein both the operating carriage and lever carriage are movable in response to movement of the single operating tension element and wherein movement of the lever carriage is arranged to be arrested by resistance exerted on the

fingers and movement of the operating carriage is arranged to be arrested by resistance exerted on the thumb during movement of the fingers and thumb towards a closed position.

Further features of the invention provide for a releasable unidirectional catch arrangement to be provided that assumes the form of a spring-loaded ratchet assembly having a manually operable release mechanism to enable unidirectional movement corresponding to closing of the fingers and thumb wherein the manually operable release mechanism is releasable by means of a manually operable release button projecting from a side of the metacarpal part opposite the thumb; for the longitudinally movable operating carriage and the longitudinally movable lever carriage to be carried on a single guide; for a thumb operating tension element to be attached to a pivotally mounted transfer lever so as to provide a reduced degree of linear movement of tension element to the thumb compared to the linear movement of the single operating tension element; for the thumb operating mechanism to include a transfer tension element having one end attached to the lever carriage and the other end attached to the thumb operating mechanism, the transfer tension element passing around a pulley on the operating carriage so as to distribute movement of the single operating tension element between the lever carriage and thence the finger operating mechanisms and the thumb operating mechanism; and for the finger operating mechanisms to be configured to apply more force to an index finger and middle finger than to a ring finger and small finger.

Still further features of the invention provide for a locking mechanism to be provided that arrests the thumb swivel element selectively in at least the two terminal positions; for the locking mechanism to be an incremental locking mechanism capable of locking the thumb swivel element in at least one intermediate position between the two terminal positions of the swivel element; for the locking mechanism to lock movement of the thumb swivel element in each of the terminal positions and any intermediate position with locking of rotational movement of the thumb swivel element being by way of formations associated with the thumb swivel element cooperating with a spring biased locking member engaging therewith in each of the terminal and intermediate locking positions; and for the thumb swivel element to be configured to enable manual movement of the thumb to project at a desired angle relative to the metacarpal part of the prosthetic hand.

Additional features of the invention provide for there to be four independent finger mechanisms extending from the metacarpal part of the hand each of which has an operating mechanism mechanically movable between an open position and a closed position by means of a finger operating mechanism; for each of the finger and thumb mechanisms to be resiliently biased to the open position by means of a helical torsion spring encircling a hinge pin; for dorsal portions of phalange elements and metacarpal part of the hand to have raised abutments for inter-engagement to arrest the fingers and thumb in the open condition; and for a portion of the

palmar surface of the metacarpal part of the hand inwards of the thumb swivel element to be formed into a resiliently biased retractable cushion member.

In order that the above and other features of the invention may be more fully understood, a more detailed description with particular reference to one embodiment of the invention will now follow with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:-

Figure 1 is a dorsal three-dimensional view of one embodiment of prosthetic hand according to the invention;

Figure 2 is a lateral view of the prosthetic hand with the thumb in its fully adducted lateral grasp terminal position;

Figure 3 is the same as Figure 2 but showing the thumb in its fully abducted power grasp terminal position;

Figure 4 is an anterior view of the prosthetic hand with the thumb in its fully adducted lateral grasp terminal position;

Figure 5 is the same as Figure 4 but showing the thumb in its fully abducted power grasp terminal position;

Figure 6 is an exploded three dimensional view showing the thumb, the thumb swivel element and the incremental locking mechanism;

Figure 7 is a transverse sectional view taken through the incremental locking mechanism;

Figure 8 is a transverse section through a thumb bearing mechanism;

Figure 9 is an open palmar view of the assembled prosthetic hand showing the lever and tension element operating mechanisms therein;

Figure 10 is a superior detailed view of the differential lever mechanism attached to the lever carriage;

Figure 11 is a three-dimensional detail showing the transfer lever whereby the thumb mechanism is operated;

Figure 12 is a section showing the transfer lever whereby the thumb mechanism is operated;

Figure 13 is an anterior lateral exploded three-dimensional view showing the wrist stem and open metacarpal part of the prosthetic hand;

Figure 14 is an exploded three-dimensional view of a finger mechanism;

Figure 15 is an enlarged lateral sectional view through an assembled finger mechanism;

Figure 16 is a three-dimensional view of a joint between the second and third phalanges of a finger mechanism showing a channel ring forming part of an operating wire path;

Figure 17 is a three-dimensional detailed exploded view of a channel ring;

Figure 18 is a transverse sectional view illustrating a resiliently biased retractable cushion member forming part of the palmar structure; and,

Figure 19 is a posterior lateral three-dimensional view of the palmar cushion member.

DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

In the embodiment of the invention illustrated in the drawings, an underactuated prosthetic hand (1) comprises a set of four independent finger mechanisms extending from a metacarpal part (2) of the hand, the finger mechanisms representing an index finger (3), a middle finger (4), a ring finger (5) and a small finger (6). Each of the finger mechanisms is mechanically movable between an open position and a closed position by means of a finger operating mechanism that will be described in more detail below.

A thumb mechanism (7) is attached to the appropriate side of the metacarpal part of the hand with the thumb mechanism having two phalange elements (8, 9) hingedly interconnected and mechanically movable between an open position and a closed position by means of a thumb operating mechanism. The thumb phalanges are hingedly attached to a thumb swivel element (11) that is rotatable about an axis (12) extending in a direction that is generally parallel to that in which the finger and thumb mechanisms extend. The thumb and thumb swivel element are rotatable between positions in which the thumb is in an adducted lateral grasp terminal position (as shown in Figures 2 and 4) and an abducted power grasp terminal position (as shown in Figures 3 and 5).

An incremental locking mechanism is provided for locking the thumb swivel element selectively in each of the two terminal positions in a releasable manner as well as in one other intermediate position. The thumb swivel element is, in this instance, rotatable through successive angles of about 30 degrees between angularly adjacent locking positions.

Locking of rotational movement of the thumb swivel element is effected by way of formations that in this instance are in the form of a series of teeth (15) of generally sinusoidal shape in cross-section on a surface of the thumb swivel element that is concentric with the axis (12) of rotation of the thumb swivel element. These teeth are engaged by complementary teeth on a relatively stationary resiliently biased locking plate (16). The thumb swivel element and incremental locking mechanism are configured to enable manual movement of the thumb to project at a desired angle relative to the metacarpal part of the prosthetic hand such as by using the user's other hand. The teeth and resilient biasing of the locking plate are selected so that a suitable degree of resistance is provided to movement of the thumb swivel element between the various possible positions relative to the metacarpal part of the hand. The various possible angular positions of the thumb and thumb swivel element are indicated by the positions of lines (17) in Figure 5.

Reverting now to more detail of the structure of the various digits, each finger mechanism has three phalange elements generally indicated by the numeral (18) with the phalange elements being hingedly interconnected and hingedly attached to the metacarpal part of the hand. Similarly, the thumb has the two phalange elements (8, 9) mentioned above with the phalange elements being hingedly interconnected and hingedly attached to the thumb swivel element.

Each of the hinged joints has a hinge pin (21) and is resiliently biased to the open position of the elements connected by the hinged joint by means of a helical torsion spring (22) encircling the hinge pin and a polymeric tubular mandrel (23). In each instance the dorsal portions of the phalange elements and metacarpal part of the hand or the thumb swivel element has a raised

abutment (24) for inter-engagement with each other in the fully open condition of the fingers and thumb.

The finger operating mechanisms include at least somewhat flexible tension elements (25) having a free end (26) that is anchored to the terminal phalange and that are interconnected as adjacent pairs by means of primary centrally pivoted levers (27), with the primary levers being pivotally attached to opposite ends of a bridging lever (28).

The bridging lever is pivotally attached to a longitudinally movable lever carriage (31) carried on a longitudinally extending guide (32) therefor within the metacarpal part of the hand with the entire mechanism being operable by a single operating tension element (33) as will be more fully described below. The guide extends in a general direction parallel to the fingers and thus in the direction of the length of the hand so that the single operating tension element may be moved in a direction away from the hand and wrist towards the forearm region of a wearer. The hand is provided at the wrist end with a screw threaded attachment stem (34).

The attachment stem (34) provides the hand with a rigid attachment interface to a prosthetic sleeve which fits onto a user patient's stump, as well as provides connectivity to a wrist/carpal mechanism which allows pronation and supination of the hand. The attachment stem (34) has a protruding spine (35) extending onto the inside of the body of the metacarpal part of the hand that is secured to the body by a series of longitudinally spaced fasteners to generate stability in the transverse plane. Four self-tapping screws fix the guide and spine to the inner dorsal surface of the palmar body of the metacarpal part of the hand.

The actuation of each finger mechanism is inspired by the natural tendon-sheath mechanism of a human hand. A tension member may be in the form of a nickel-titanium wire that passes through channels (37) within each of the phalanges and secured at its free end by means of a welded bead, a crimped ferrule or a knot (26). These channels (37) have a cross-sectional profile similar to the Greek letter Omega (Ω) and are longitudinally arched in side view to increase the leverage of the wire about the hinge pin (21) of each joint, as shown in Figure 15. This is intended to benefit a patient greatly as the activation energy needed to rotate the joint is expected to be reduced thereby reducing the physical exertion needed to close the hand. This also reduces the required wire tension, which reduces the wire contact forces (in the normal direction) and ultimately decreases wear on the mechanism.

The Omega "Ω" cross-section allows for the insertion of two types of reinforcing structures or linings of either cylindrical or plate material. Helical hollow strand tubing is used for the channel (37) and a bent flat metallic plate (38) may be selected. The tubing and plate may be located

securely within the channel structure by punched channel rings (39) on each end to prevent axial movement. The channel rings (39) may be glued into position, and channel ring retainers (41), projecting from and being part of the parent material, may be heated and bent over the channel ring (39) to secure it in position.

As shown in Figures 9 and 10 the primary lever associated with the index and middle fingers is somewhat closer to the pivotal attachment of the bridging lever than the primary lever associated with the ring and small fingers so that somewhat more force is applied to the index finger and middle finger than to the ring finger and small finger when the single operating tension member is pulled. This achieves an uneven force distribution that favours force exerted by the index and middle fingers over that exerted by the ring and small fingers.

A thumb operating tension element (42) that may also be in the form of a nickel-titanium wire is attached to an intermediate position on a pivotally mounted transfer lever (43) that has its pivot (44) at one of its ends and is attached to a transfer tension element (45) at its other end. The transfer tension element (45) is attached to the lever carriage (31) as ids further described below. The result is a reduced degree of linear movement of the thumb operating tension element (42) compared to the possible linear movement of the single operating tension element (33).

The thumb operating tension element (42) is routed from the thumb and attaches to the central region of the thumb operating tension element on the pivotally mounted transfer lever (43).

The transfer tension element (45) runs from the free end of the transfer lever around two needle-roller routing-bearings located distally within the palm and thence around a large flanged transfer-pulley (55) on an operating carriage (40) which moves on the guides on the proximal side of the lever carriage and with the free end of the transfer tension element being attached to the lever carriage. The single operating tension element (33) is attached to the operating carriage. The operating carriage is movable along the same guides (32) as the lever carriage (31) and the two typically abut each other in a non-functional position corresponding to a totally open condition of the hand. The transfer pulley (55) thus distributes movement of the operating carriage that is moved in unison with the single operating tension element (33) between the pivotally mounted transfer lever (43) that cooperates the thumb and the lever carriage that operates the finger mechanisms. In this way the single operating tension element serves both purposes of moving the thumb mechanism and the finger mechanisms as will be clear from a reference to Figure 9.

By way of explanation, the operating and lever carriages are illustrated in Figure 9 at positions that may be acquired at some stage of travel of the mechanism inside the hand. An attempt has not been made to illustrate these carriages in their positions of rest with the hand fully open as all parts need to move in synchronisation and once the fingers are closed they will be in the way of viewing of the mechanism.

The operating carriage (40) has associated with it a releasable unidirectional catch arrangement that includes a spring-loaded ratchet assembly having a relatively stationary pawl (46) engaging a longitudinally extending rack (47) movable in unison with the operating carriage. A manually operable release mechanism has a manually operable release button (48) projecting from the side of the metacarpal part of the hand opposite the thumb. The unidirectional movement is permitted in a direction corresponding to that of closing of the fingers and thumb.

The purpose to be served by the separate operating carriage is to allow limited independent movement of the fingers and thumb, for example, when picking up a flat object (such as a folder or plate) the fingers can remain in their open position (lever carriage forward and stationary) and the thumb can close (operating carriage retracts). Initial pulling on the operating carriage by way of the single operating tension element (33), if there is no resistance offered by the fingers, results in the lever carriage and the operating carriage moving in unison and all digits closing in unison. As soon as the fingers are subjected to resistance, the operating carriage continues to move whilst the lever carriage may stop and allow a gap to develop between the carriages until a desired grasp is achieved. In this way limited independent movement between the two carriages is enabled and thus some independent movement of the fingers and thumb. Once the fingers encounter resistance the thumb will complete the remainder of the closing motion until a required grip force is established. Figure 9 illustrates the operating carriage spaced from the lever carriage, as indicated above.

In each instance in which a tension element such as the tension element (45) changes direction and passes around a pulley, the pulley may assume the form of a bearing (49), as shown in Figure 8, and end caps (50) may define a central path for the tension element.

Rotation of the release button when it is depressed ensures that the pawl is maintained in a disengaged position. This may be required if a motor is attached to the hand, or when the patient wishes to use the hand without incremental locking so that locking is completely bypassed. This may be required, for instance, if a user wishes to pick an object up and release it quickly without having to use the release button.

Finally, in order to enhance the grip that is afforded by the hand, a portion of the palmar surface of the metacarpal part inwards of the thumb swivel element is formed into a resiliently biased retractable palmar cushion member (51). The palmar cushion uses potential spring energy stored in the springs (52) to assist in the whole or partial absorption of any slack in the actuating system. The main objective is to maintain normal contact-forces between the hand and a gripped object, when the tension in the single operating tension element (33) is released by the user.

The cushion member (51) opens and closes through an angle of about 15° with two torsional spring elements (52) between the cushion member (51) and a backing surface (53), maintaining the rest position as fully-opened. The cushion member (51) pivots about a central axis (54) of distal and proximal pins. Three protrusions or stems (58) are positioned on the medial side of the palmar cushion (51), and locate within slots (59) to limit the angle to which the palmar cushion (53) may open. Additionally, the protrusions or stems also serve to prevent hyperextension of the palmar cushion (51), should the mechanism encounter any unforeseen hyper-extensive loading.

Numerous variations may be made to the embodiment of the invention described above without departing from the scope hereof, as will be quite apparent to those of ordinary skill in the art.

Throughout the specification and claims unless the contents requires otherwise the word 'comprise' or variations such as 'comprises' or 'comprising' will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

CLAIMS:

1. An underactuated prosthetic hand comprising a plurality of independent finger mechanisms extending from a metacarpal part of the hand whereof at least selected finger mechanisms are mechanically movable between an open position and a closed position by means of a finger operating mechanism that includes tension elements that are interconnected by means of levers so as to be operable by a single operating tension element, and a thumb mechanism attached to one side of the metacarpal part of the hand with the thumb mechanism also being mechanically movable between an open position and a closed position by means of a thumb operating mechanism that includes a tension element; wherein the thumb is attached to the metacarpal part of the hand by way of a thumb swivel element that is rotatable about an axis extending in a direction that is the same as that in which the finger and thumb operating mechanisms extend such that the thumb swivel element is rotatable between positions in which the thumb is in an adducted lateral grasp terminal position and an abducted power grasp terminal position, the underactuated prosthetic hand being characterized in that a single operating tension element is connected to a longitudinally movable operating carriage associated with operation of the thumb mechanism and a longitudinally movable lever carriage is associated with the finger mechanisms wherein both the operating carriage and lever carriage are movable in response to movement of the single operating tension element and wherein movement of the lever carriage is arranged to be arrested by resistance exerted on the fingers and movement of the operating carriage is arranged to be arrested by resistance exerted on the thumb during movement of the fingers and thumb towards a closed position.

2. An underactuated prosthetic hand as claimed in claim 1 in which a releasable unidirectional catch arrangement that assumes the form of a spring-loaded ratchet assembly having a manually operable release mechanism is provided to enable unidirectional movement corresponding to closing of the fingers and thumb wherein the manually operable release mechanism is releasable by means of a manually operable release button projecting from a side of the metacarpal part opposite the thumb.

3. An underactuated prosthetic hand as claimed in either one of claims 1 or 2 in which the longitudinally movable operating carriage and the longitudinally movable lever carriage are carried on a single guide.

4. An underactuated prosthetic hand as claimed in any one of the preceding claims in which a transfer tension element is attached to a pivotally mounted transfer lever so as to provide a reduced degree of linear movement of tension element to the thumb compared to the linear movement of the single operating tension element.

5. An underactuated prosthetic hand as claimed in any one of the preceding claims in which the thumb operating mechanism includes a transfer tension element having one end attached to the lever carriage and the other end attached to the thumb operating mechanism, the transfer tension element passing around a pulley on the operating carriage so as to distribute movement of the single operating tension element between the lever carriage and thence the finger operating mechanisms and the thumb operating mechanism.

6. An underactuated prosthetic hand as claimed in any one of the preceding claims in which the finger operating mechanisms are configured to apply more force to an index finger and middle finger than to a ring finger and small finger.

7. An underactuated prosthetic hand as claimed in any one of the preceding claims in which a locking mechanism arrests the thumb swivel element selectively in at least the two terminal positions.

8. An underactuated prosthetic hand as claimed in claim 7 in which the locking mechanism is an incremental locking mechanism capable of locking the thumb swivel element in at least one intermediate position between the two terminal positions of the swivel element.

9. An underactuated prosthetic hand as claimed in either one of claims 7 or 8 in which the locking mechanism locks movement of the thumb swivel element in each of the terminal positions and any intermediate position with locking of rotational movement of the thumb swivel element being by way of formations associated with the thumb swivel element cooperating with a spring biased locking member engaging therewith in each of the terminal and intermediate locking positions.

10. An underactuated prosthetic hand as claimed in any one of the preceding claims in which the thumb swivel element is configured to enable manual movement of the thumb to project at a desired angle relative to the metacarpal part of the prosthetic hand.

11. An underactuated prosthetic hand as claimed in any one of the preceding claims in which there are four independent finger mechanisms extending from the metacarpal part

of the hand each of which has an operating mechanism mechanically movable between an open position and a closed position by means of a finger operating mechanism.

12. An underactuated prosthetic hand as claimed in any one of the preceding claims in which each of the finger and thumb mechanisms are resiliently biased to the open position by means of a helical torsion spring encircling a hinge pin.

13. An underactuated prosthetic hand as claimed in any one of the preceding claims in which dorsal portions of the phalange elements and metacarpal part of the hand have raised abutments for inter-engagement to arrest the fingers and thumb in the open condition.

14. An underactuated prosthetic hand as claimed in any one of the preceding claims in which a portion of the palmar surface of the metacarpal part of the hand inwards of the thumb swivel element is formed into a resiliently biased retractable cushion member.

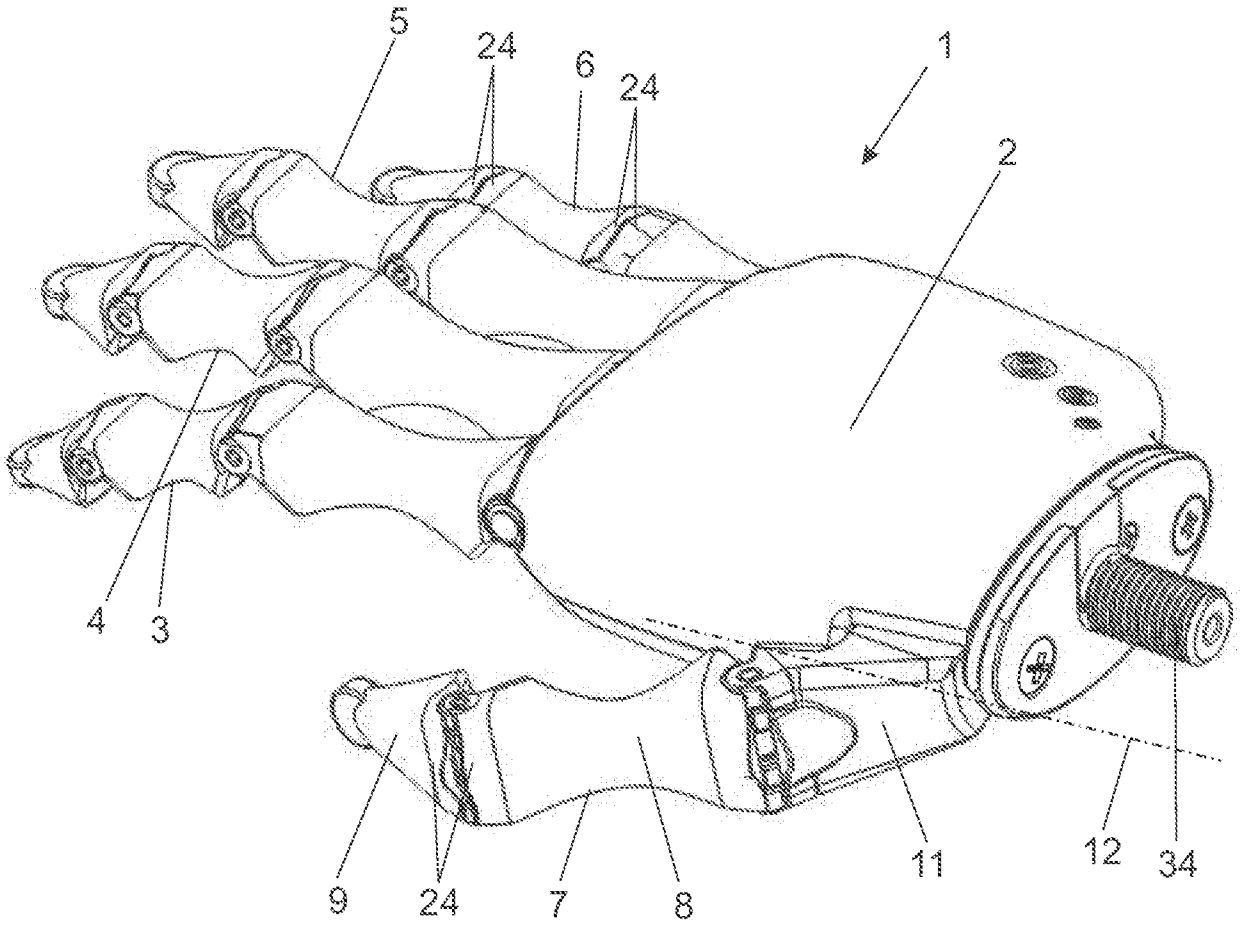


Figure 1

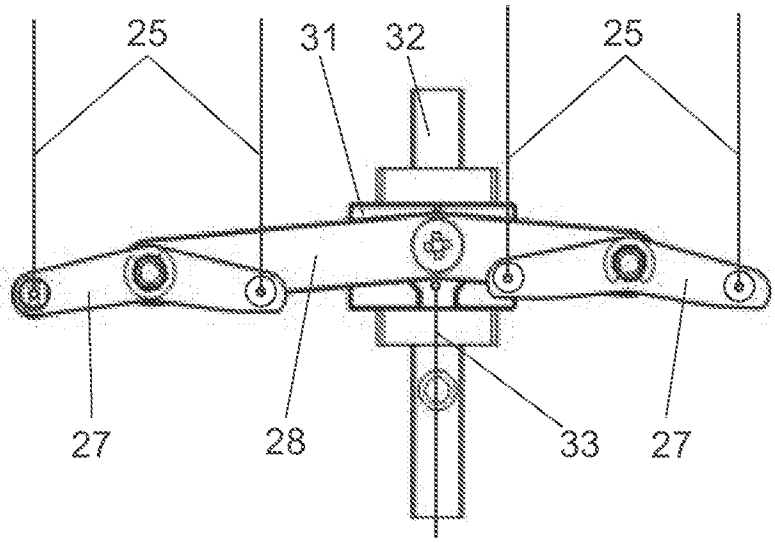


Figure 10

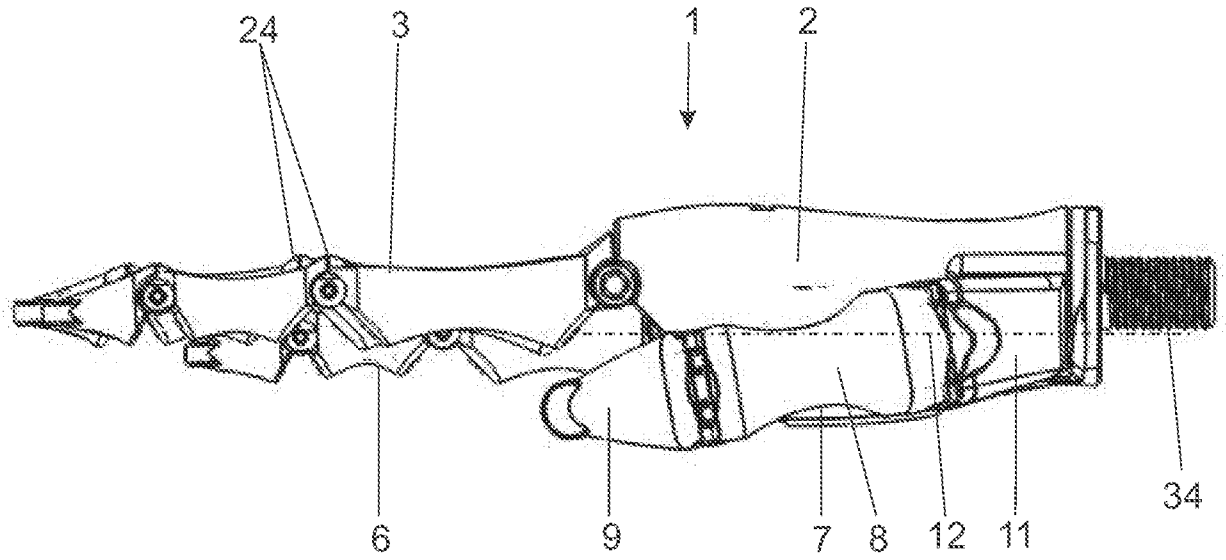


Figure 2

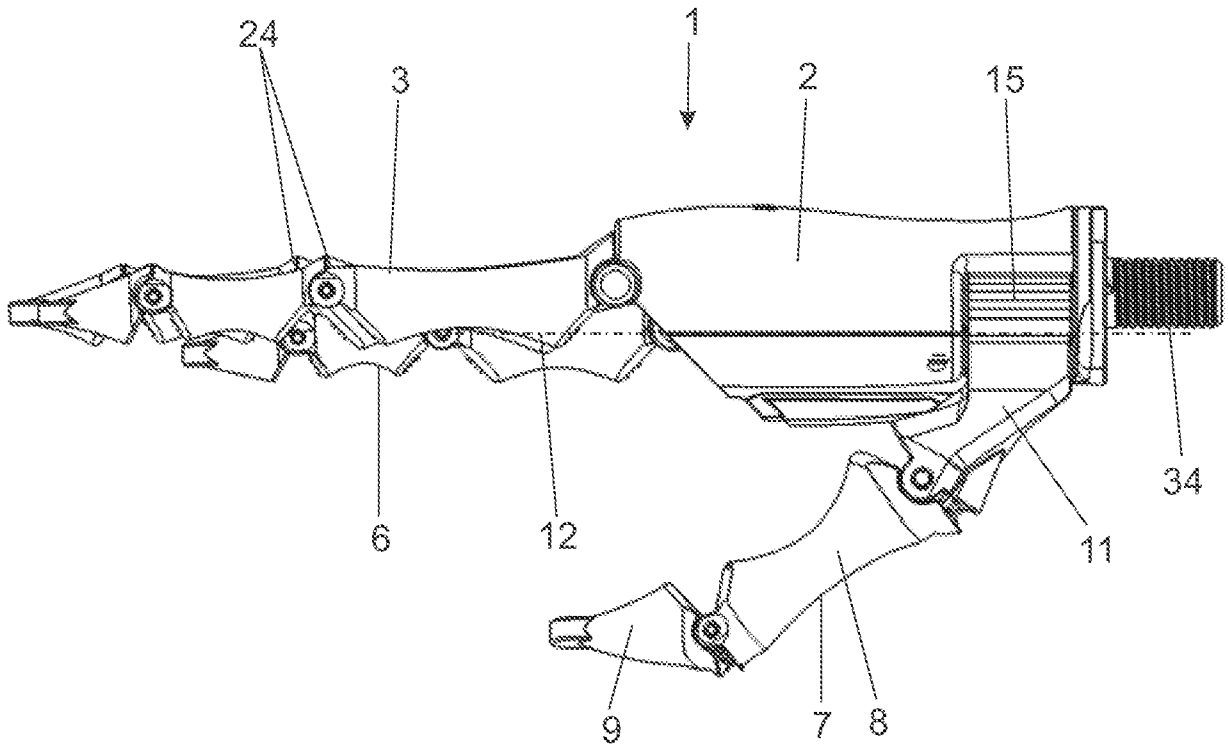


Figure 3

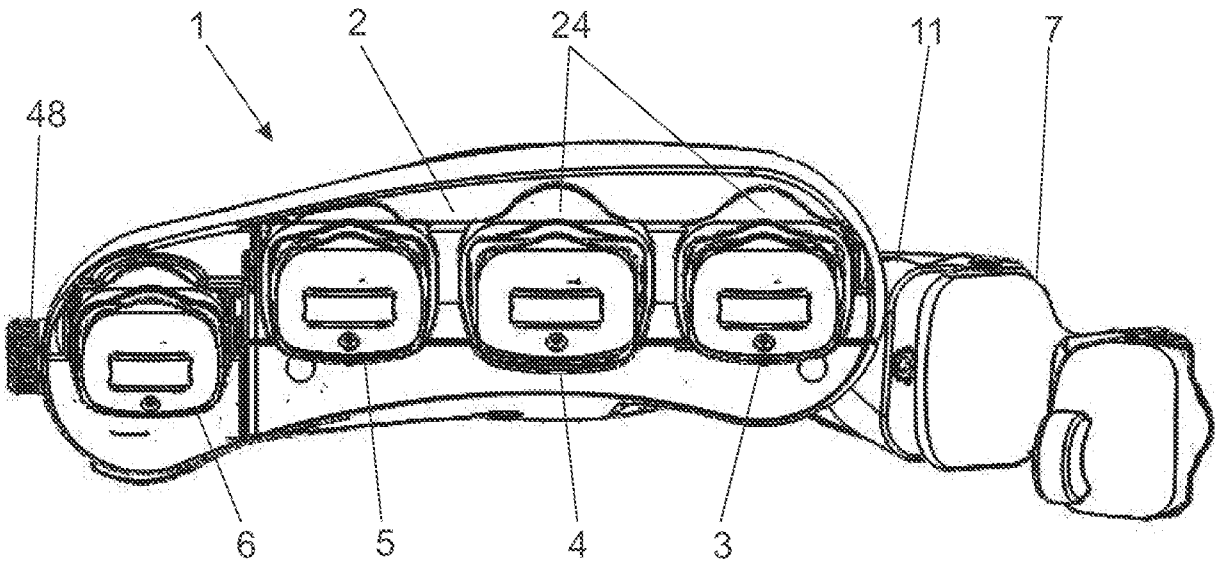
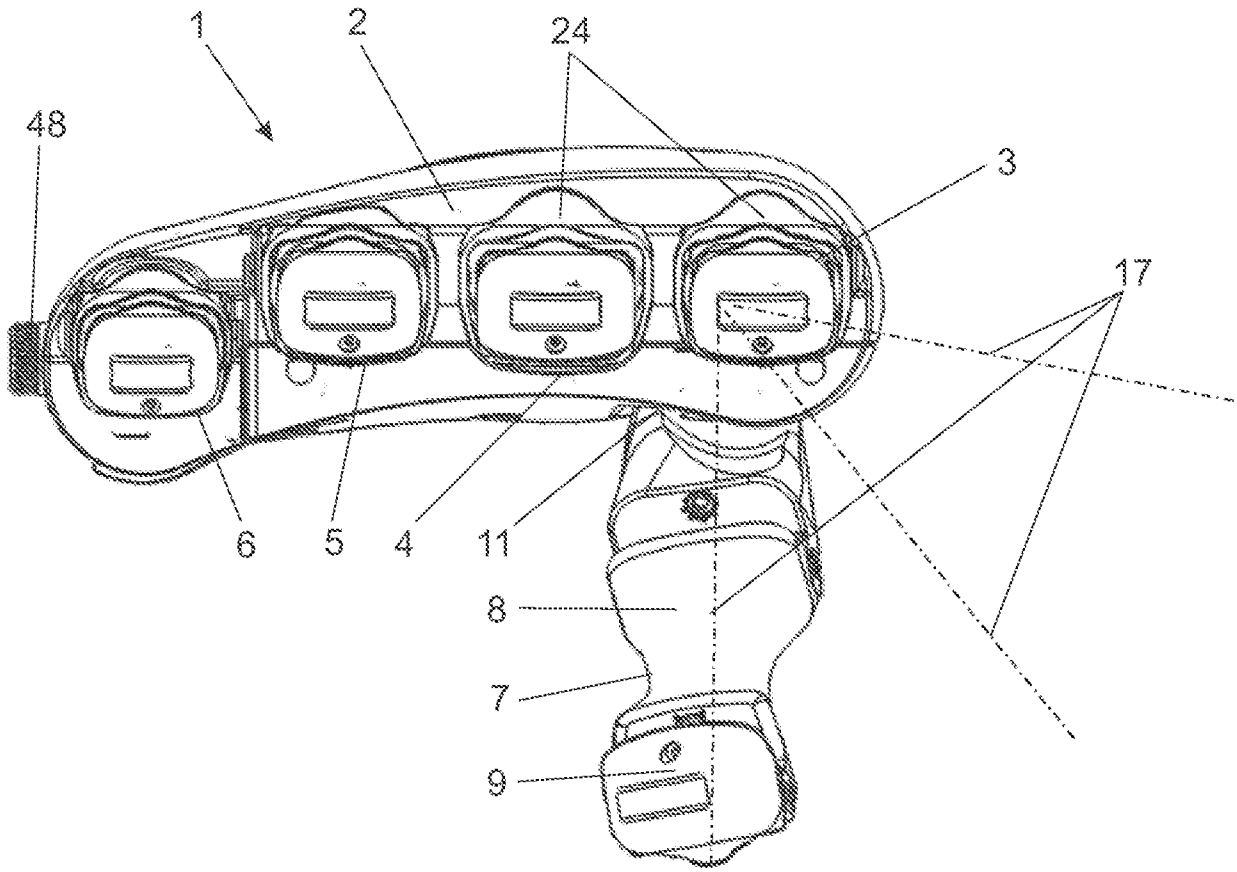


Figure 4



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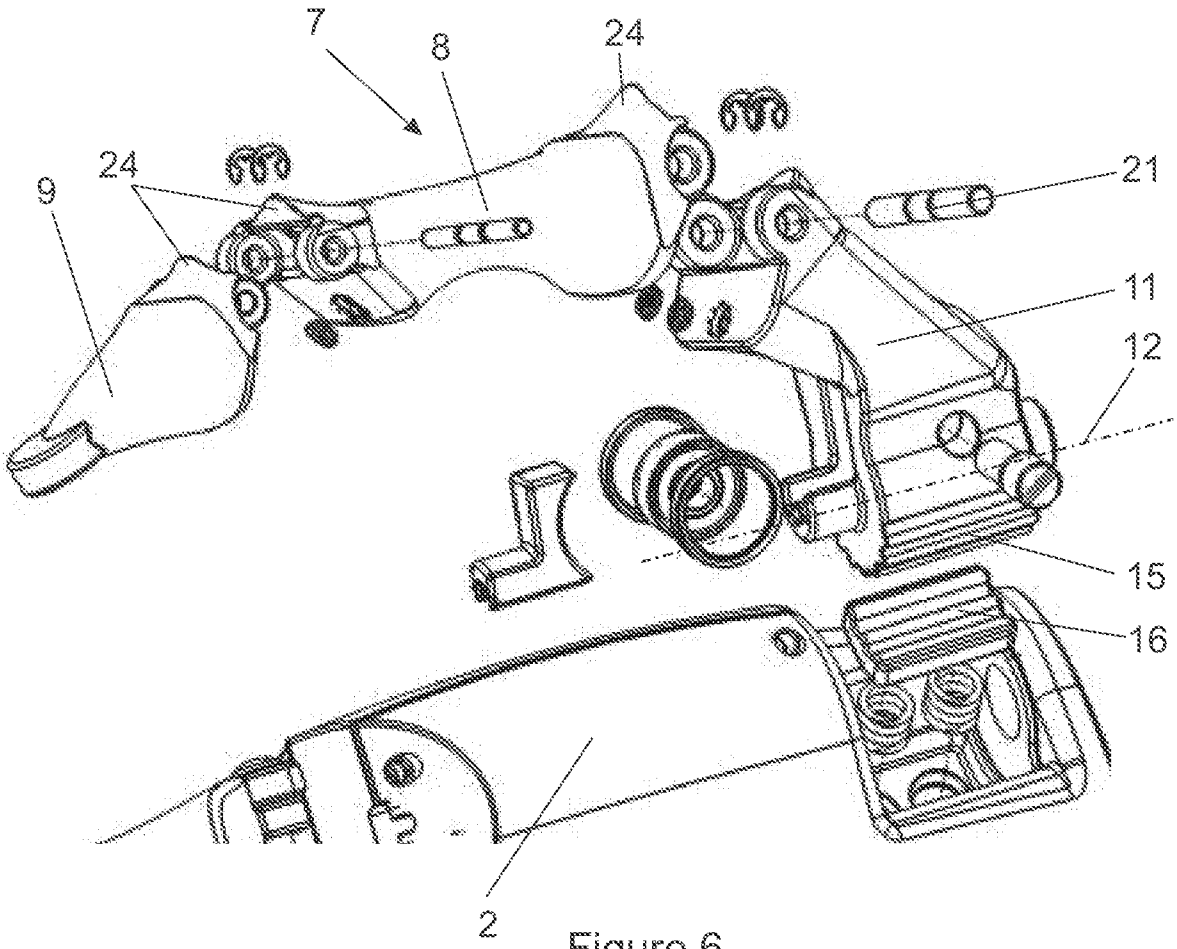


Figure 6

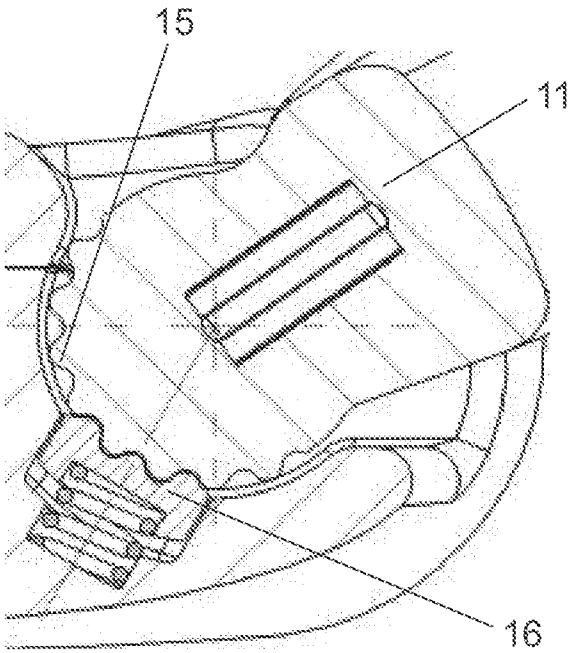
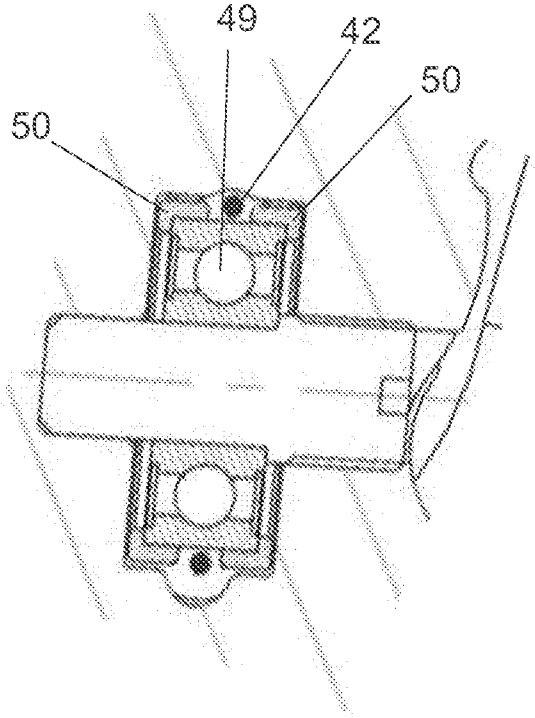


Figure 7



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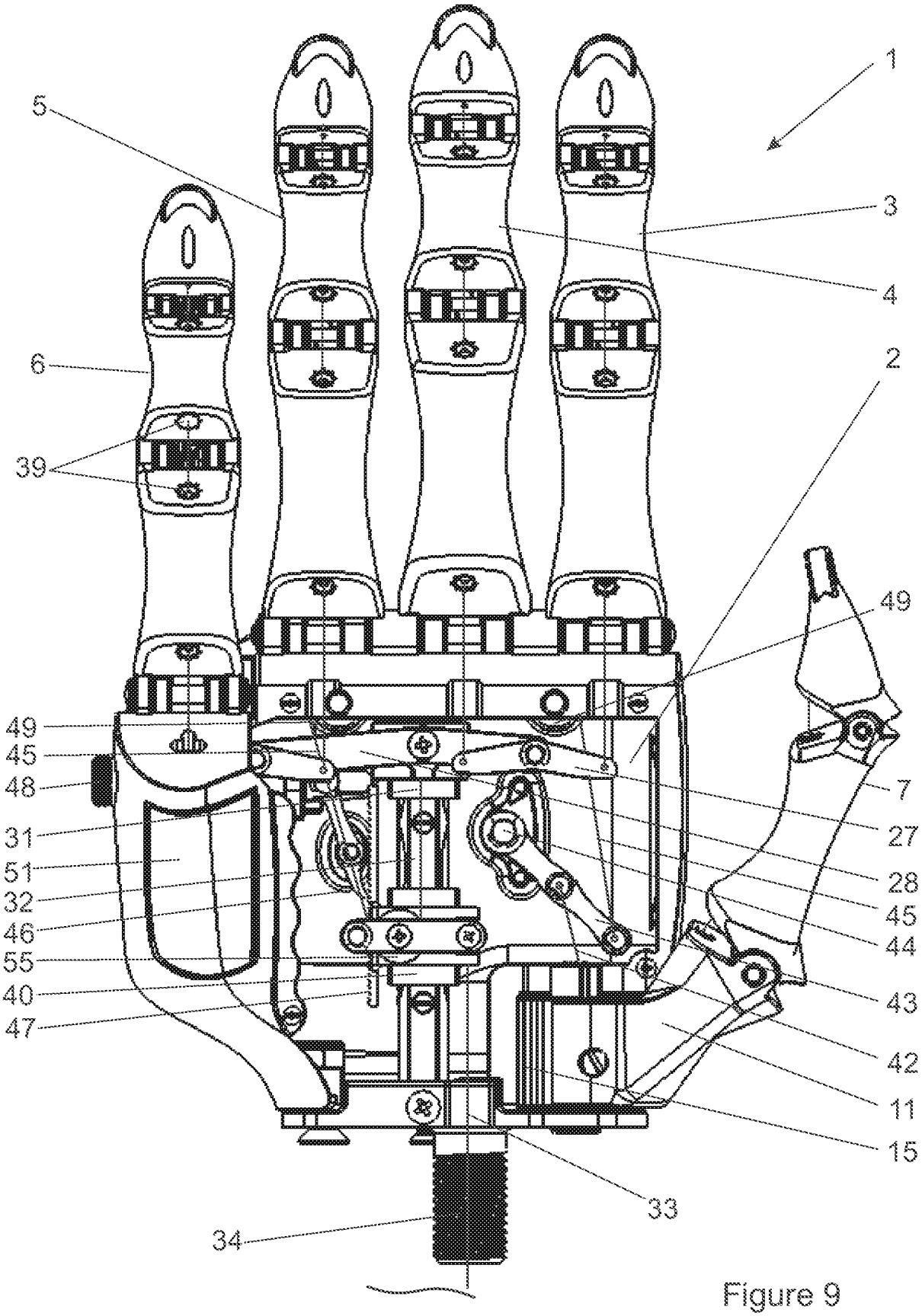
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Figure 9

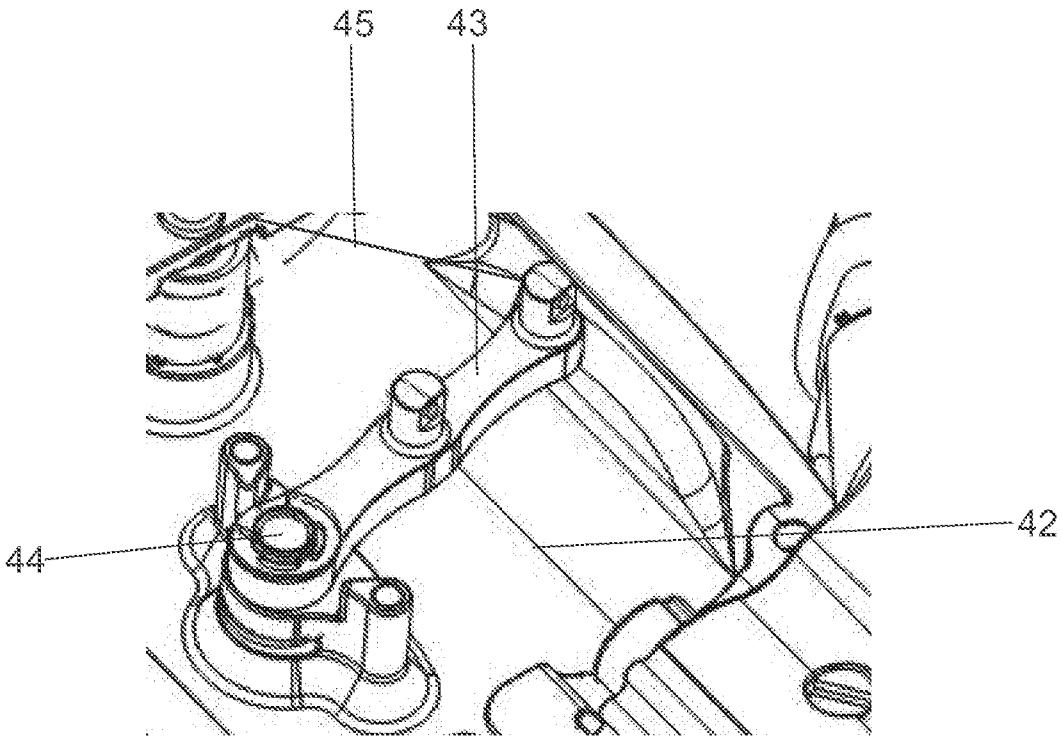

Figure 11

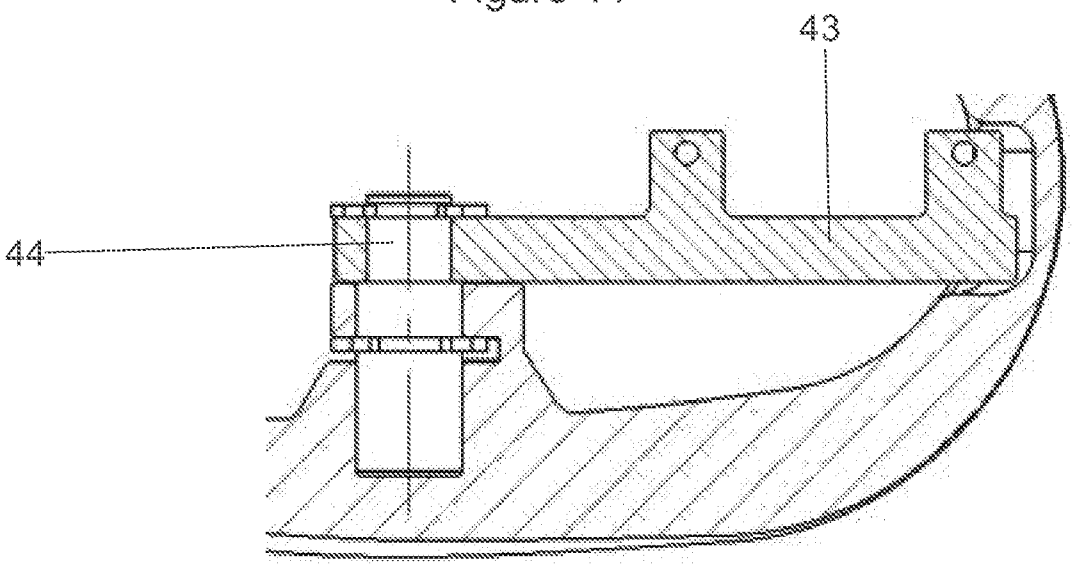

Figure 12

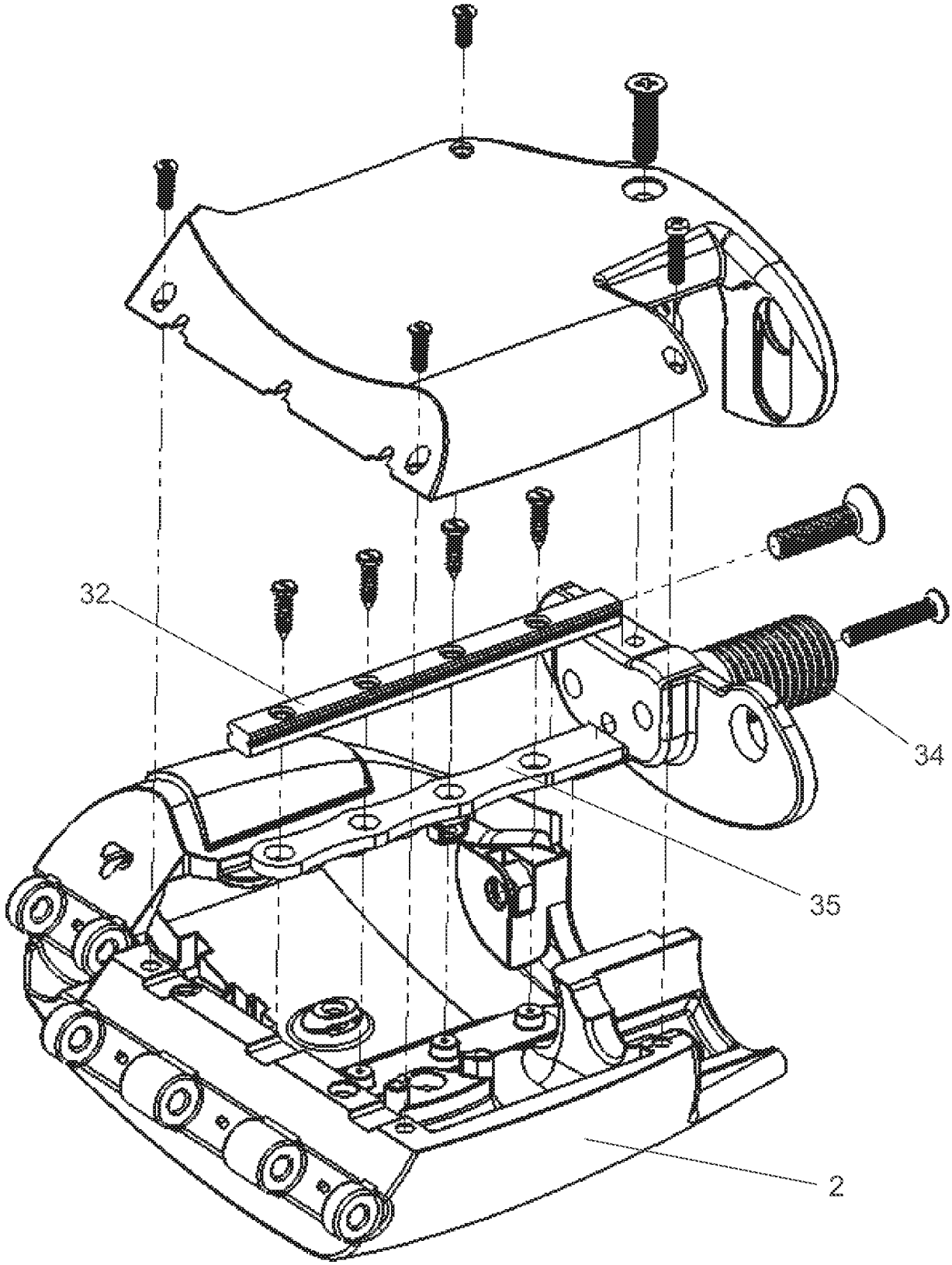

Figure 13

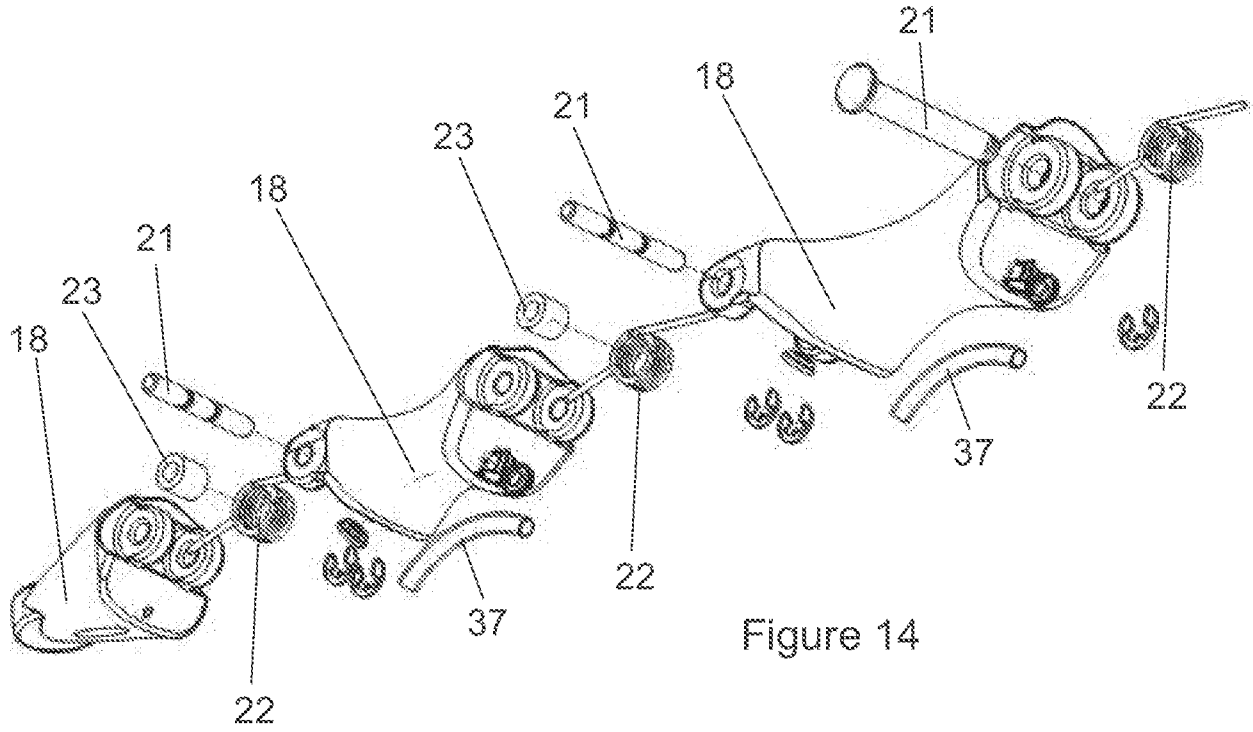

Figure 14

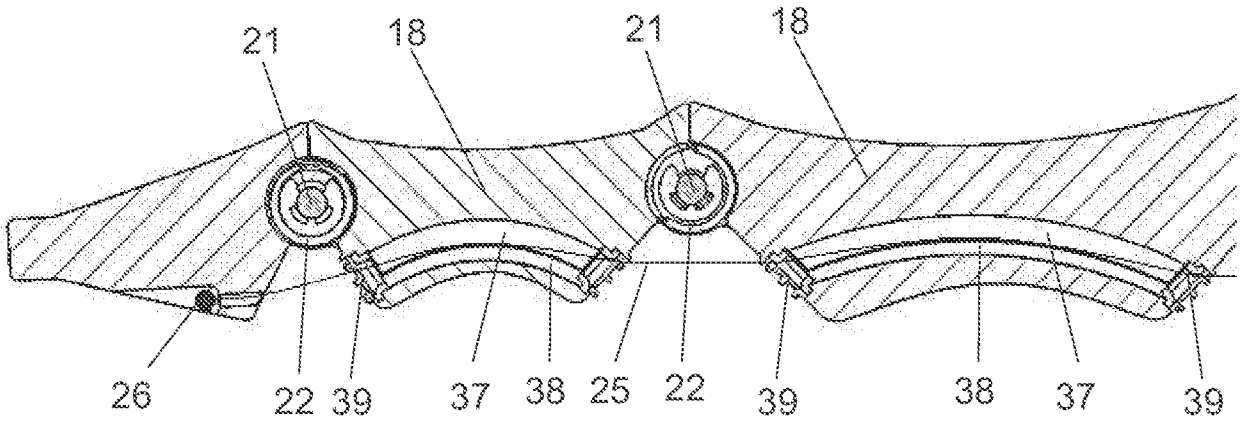

Figure 15

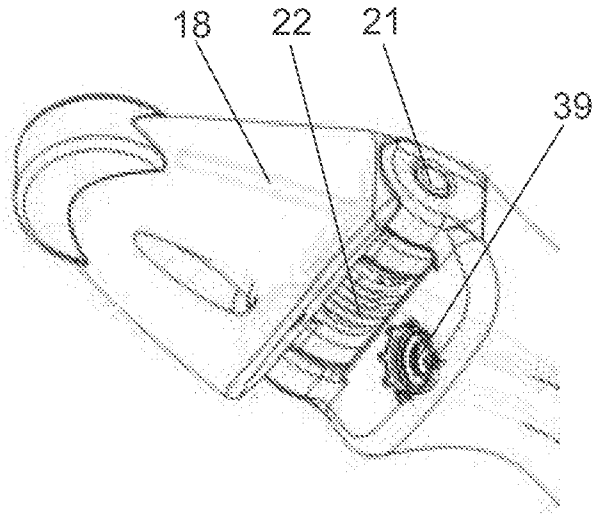

Figure 16

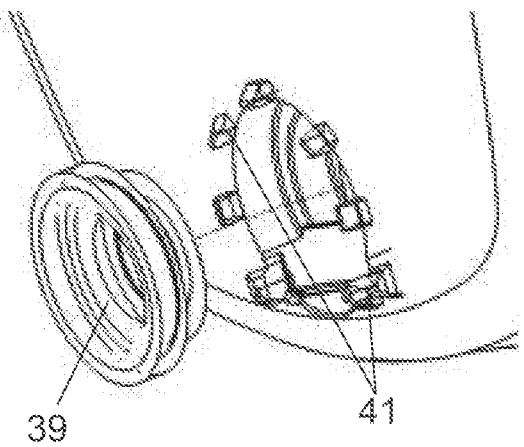

Figure 17

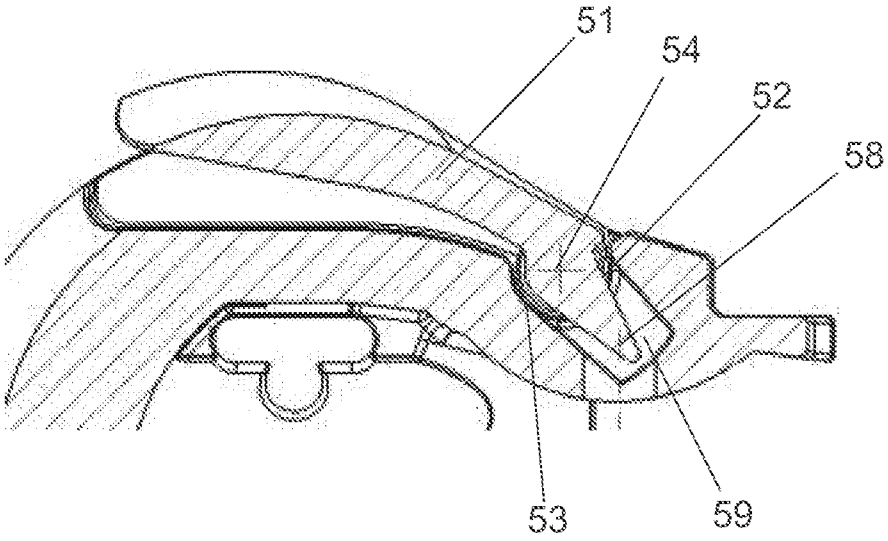

Figure 18

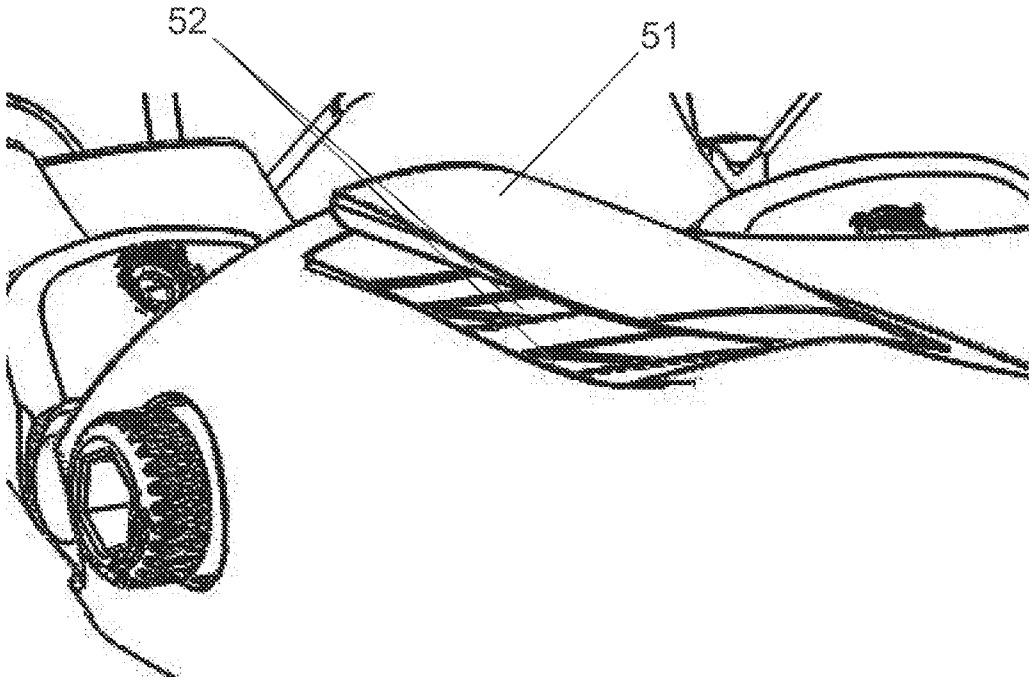

Figure 19

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/055078

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F2/58 A61F2/68
ADD. B25J15/00

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 457 294 A1 (HONDA MOTOR CO LTD [JP]) 15 September 2004 (2004-09-15) paragraph [0042] - paragraph [0068]	1-14
A	WO 2013/185231 A1 (UNIV LAVAL [CA]) 19 December 2013 (2013-12-19) the whole document	1-14
A	FR 2 957 245 A1 (FELTRIN OSCAR [IT]; FELTRIN ADELINE MARIE THERESE BERNHARDT [IT]) 16 September 2011 (2011-09-16) the whole document	1-14
A	WO 2013/076683 A1 (UNIV CAPE TOWN [ZA]) 30 May 2013 (2013-05-30) the whole document	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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	Date of mailing of the international search report
22 October 2015	04/11/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lickel, Andreas

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2015/055078

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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FR 2957245 A1	16-09-2011	NONE	
WO 2013076683 A1	30-05-2013	NONE	