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(54) **Device and process for adjusting the height of and the relief force acting on a weight**

(57) A device for adjusting the height of and relief force acting on a weight is especially provided to be used for walking therapy of paraparetic or hemiparetic patients within a locomotion training means. Said weight of the patient is supported by a cable (11, 30). A first cable length adjustment means (1) provides an adjustment of the length of the cable (11) to define the height of said suspended weight. A second cable length adjustment means (2) provides an adjustment of the length of the cable (11) to define the relief force acting on the suspended weight. This allows a quick and reliable determination and adjustment of the height for different patients and of the relief force within the training program of every patient.

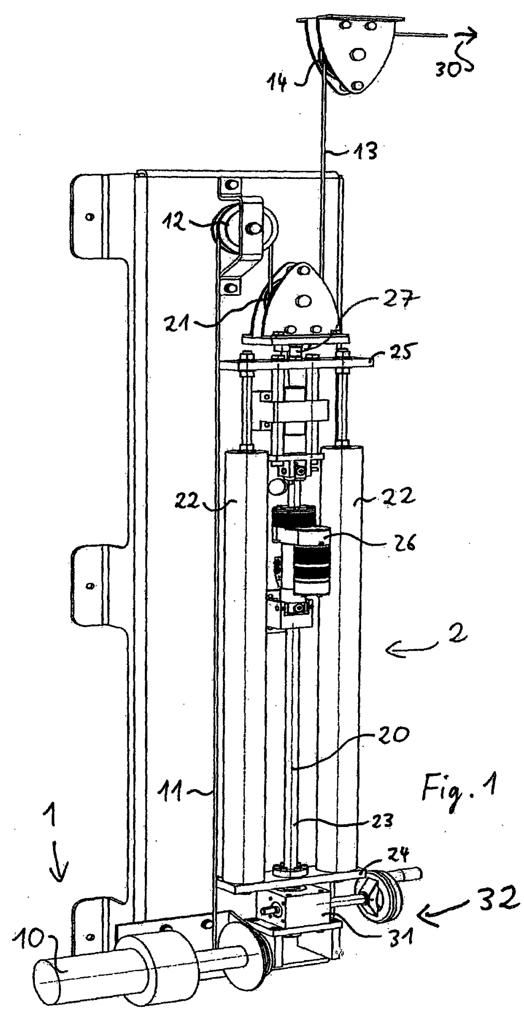

Fig. 1

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Description

Field of the invention

[0001] The present invention relates to a device and a process for adjusting the height of and the relief force acting on a weight, especially on the weight of a patient within a locomotion training means to be used for walking therapy of paraparetic or hemiparetic patients. In other words, the invention relates to an automatic unloading device that allows unloading an object attached to one end of a rope by a precise counter force. Especially, the invention relates to a device and a process which can be used within a locomotion training of patients with walking impairments in any phase of rehabilitation.

Background of the invention

[0002] As mentioned above said type of unloading system can be used for different applications but is preferably intended for the use in body weight supported treadmill training. This type of training is for example being used to train neurologically impaired patients to walk again during rehabilitation. For such incomplete paraplegic patients the possibility exists of improving walking ability up to normality by means of an adequate locomotion training. The required therapy at present takes place on a treadmill, where walking is first made possible for the patient by defined weight relief and partially by additional assisting guidance of the legs by physiotherapists (Wickelgren, I. Teaching the spinal cord to walk. Science, 1998, 279, 319-321).

[0003] In the rehabilitation of patients with limited motion of the legs or after orthopedic operations, various driven orthoses are already in use which actively move the legs of recumbent patients. During body weight supported treadmill training, a patient is walking on a treadmill, while he is partially suspended from part of his body weight.

[0004] EP 1 137 378 discloses an automatic machine which is used in treadmill therapy (walking therapy) of paraparetic and hemiparetic patients and which automatically guides the legs on the treadmill. Said machine consists of a driven and controlled orthotic device which guides the legs in a physiological pattern of movement, a treadmill and a relief mechanism. The knee and hip joints of the orthotic device are each provided with a drive. Said orthotic device is stabilized on a treadmill with stabilizing means in such a manner that the patient does not have to keep his/her equilibrium. The orthotic device can be adjusted in height and can be adapted to different patients.

[0005] The unloading is achieved by a counterweight that is attached to the other end of a rope, which is connected to the patient by a harness. This is by definition a simple method and the results are often acceptable for regular treadmill training. However, there are some disadvantages in using this method for this kind of therapy. One disadvantage is occurring if the patient has to be suspended by a large amount of his body weight. If a large mass has to be attached on the other side of the rope the inertia of the mass is causing large forces during the up and down acceleration of the body. Also, it is not very easy to change the amount of unloading during the training with most of the conventional counterweight systems. Either the therapist has to lift weight to or from the system to change the suspension or the patient has to be lifted by a winch to be able to connect additional counterweights to the system.

[0006] Prior art discloses devices to provide a reliable positioning of the device height, but are cumbersome to adapt to different patients. Another limitation of this approach is furthermore the limited liberty of changes to be made in the course of the application of the walking program for the patient.

[0007] One object of the invention is therefore to describe a device allowing faster response times and more precise determination of the height of the patient's position and of the relief force.

Summary of the invention

[0008] The present invention relates on the insight that the functions of the cable adjustment means have to be separated to be able to achieve an electronically controlled fast adjustment of the relief force.

[0009] The set object is met in accordance with the invention by means of a device in accordance with the wording of claim 1.

[0010] The features according to claim 1 uses two different cable length adjustment means. One is provided to adjust the length of the cable to define the height of the suspended weight. The other is provided to adjust the length of the cable to define the relief force acting on the suspended weight.

[0011] The invention enhances the control of height and relief force through the separation of the functions. The height of the weight depends on the patient, whether he is a tall or a small person. This is adjusted at the beginning of a training session. The corresponding device can act slowly, even manually. The relief force has to be controlled during the actual therapy. The second cable length adjustment means divides the necessary relief force in a first static part, providing an approximate force response, and a second dynamic part, providing the fast fluctuations of the relief force while the patient is walking.

[0012] Further preferred embodiments of the apparatus according to the invention are characterized in the dependent claims.

[0013] In order to adapt the principles of the invention to a larger range of instruments the different devices are motorized and connected to a computer means with memory, the memory comprising database entries for different patients (height of suspension and intended general relief force) and different walking therapies (fine tuned relief force programs). This allows a quick and reliable determination and adjustment of the height for different patients and of the relief force within the training program of every patient.

[0014] A benefit of the device according to the invention is therefore that any patient can readily mount the apparatus to use the treadmill therapy, which is very easy to adjust for his needs. No special preparation of the treadmill, and no dedicated elastic means are required.

Brief description of the drawings

[0015]

Fig. 1 shows a perspective view of a device according to one embodiment of the invention, and

Fig. 2 shows a schematic diagram of the controller in combination with the device according to Fig. 1.

Detailed description of the invention

[0016] Fig. 1 shows a perspective view of a device for adjusting the height of and relief force acting on a weight according to one embodiment of the invention.

[0017] The device comprises two main components: one static part 1 and another dynamic part 2. The static component 1 comprises a winch 10 controlling a primary cable 11 to which the patient is attached. In the embodiment shown the primary cable 11 fixed at the turning sleeve of the winch 10 is running preferably parallel to the longitudinal main axis 20 of the dynamic part 2 of the device. Said longitudinal main axis 20 is directed vertically to the ground.

[0018] Cable 11 is redirected by a fixed roller 12 towards the dynamic part 2 of the device, engages the moving roller 21 being part of said dynamic part 2 and leaves the dynamic part 2 as adjusted cable portion 13 of the cable 11. The cable 11 is then leaving the device redirected by one or more fixed rollers 14; the corresponding prolongation of the cable 11 has received the reference numeral 30.

[0019] A patient who intends to use a known apparatus for a treadmill therapy, e.g. according to EP 1 137 378, is attached in said prolongation 30 of the cable 11 in a harness (not shown) oriented vertically. The winch 10 is statically suspending the patient so he can not fall and therefore is also responsible for the safety of the patient per se.

[0020] Although within the preferred shown embodiment of the invention winch 10 is used to statically adjust the length of cable 11 provided to said harness, it is also possible to fix cable 11 at the location of the winch 10 and to provide a drive unit connected to the fixation of a roller upstream of the dynamic part 2, e.g. roller 12, so that said roller 12 can be moved in direction of longitudinal axis 20. In another embodiment not shown in the drawings it can be a roller (or a combination of rollers) downstream of the dynamic part 2, e.g. roller 14, being mounted with a drive unit so that said roller(s) 14 can be moved in direction of longitudinal axis 20 to adjust the length of the cable 11 provided to attach a patient. Within a third embodiment the static part 1 comprises a unit connected to the frame 32. In slid case the static part 1 does not act directly on the cable. Said unit is provided to move frame 32 in the direction of longitudinal axis 20. With a fixed end of cable 11 said movement of frame 32 moves roller 21 and therefore lengthens or shortens the free cable 13.

[0021] All these alternative units for winch 10 can constitute the static part 1 of the device to provide a static adjustment of the length of the cable 11 provided in said prolongation 30 which corresponds to the intended height of the harness for use in a walking therapy.

[0022] The dynamic part 2 comprises an elastic means. The elastic means of the embodiment is a spring means 22 provided as two helicoidal springs provided on either side of a central spindle 23. Beside the use of helicoidal springs 22 it is also possible to use different types of elastic means, being able to exert a force in the approximate range of the intended weight to be attached to the prolongation 30 of the cable 11.

[0023] Springs 22 are attached between a bottom plate 24 and a top plate 25. The bottom plate 24 is attached to a spindle drive 31 connected with spindle 23 engaging a thread within bottom plate 24. Spindle drive 31 shows a handle but can also be motorized and connected to a control unit. Top plate 25 is connected to a pulley 21, pulling the cable 11 down. Through use of the redirection of cable portion 13 the rollers 12, 14 and 21 have the function of a pulley-block. It can be intended to use even more redirections to translate the adjustment of the cable length of the prolongation 30 into a much smaller movement of the pulley 21.

[0024] In parallel with the springs 22, i.e. parallel to the axis 20, there is a linear drive 26 attached to the pulley 21 via the top plate 25. By this linear drive 26 the force of the springs 22 can be reduced or enhanced. Between the pulley 21 and the dynamic control component acting on the springs 22 and linear drive 26, there is a force transducer 27 that measures exactly how much force is being applied to the rope 13 by the pulley 21. The force transducer 27, connected in series to elastic means 22, is connected to a electronic control unit. The control unit is preferably forming a closed loop control unit.

[0025] The linear drive 26 is controlled by said electronic control unit, e.g. provided as a computer system, through a closed loop controller in such a way, that the force acting on the force transducer 27 can be controlled precisely. The force acting on the force transducer 27 is directly proportional to the force acting on cable 13 at the harness. The force transducer 27 can also be mounted to measure the force acting on the pulley 14, on the pulley 12 or near the patient at the other side 30 of the cable 11, being the connecting link to a harness supporting the patient (weight 40).

[0026] A treadmill training of a neurologically impaired patient can be performed as follows: First the patient, attached to the other side 30 of the cable 11 with a harness, would be suspended over the walking surface by the winch 10 (static unloading system 1) until standing.

[0027] The amount of unloading is defined by the control unit. A small motor attached to the spindle drive 31 that determines the tension of the springs 22 would then extend the springs 22 up to a length that more or less corresponds to the desired unloading of the patient. Like this the dynamic system is already unloading the patient nearly with the desired force.

[0028] This closed loop control of body weight support allows for perfect accommodation of partial weight bearing exercise.

[0029] The up and down movement of the patient causes the force to be not constant during the training if only the springs 22 were attached. Therefore the linear drive 26 will adjust the position of the pulley 21 online, as controlled by the close loop controller, so the force acting on the rope 11 will be constant, or corresponding to a desired force trajectory, during the whole training.

[0030] The device can only guarantee a precise, desired unloading, as long as the weight can be adjusted by the linear drive 26. This is not possible anymore, if the patient moves up or down too much, meaning that the linear drive 26 is approaching the end of the range of motion. This is detected by the control unit, as the movement of the linear drive 26 is measured with a position sensor, e.g. a ultrasound transducer mounted beneath top plate 25. The control unit can therefore readjust the position of the patient with the winch 10 in terms to bring the linear drives 26 back into the range of operation.

[0031] Fig. 2 shows a schematic diagram of the electronic controller unit in combination with the device according to Fig. 1. The winch 10, the actuator 26, e.g. the linear drive, and the bias means 31, e.g. the spindle drive, are shown receiving an controller signal I and outputting a signal proportional to a well-defined force F or position x. The boxes of Fig. 2 showing a actual device according to Fig. 1 have received the same reference numeral, although it is clear for someone skilled in the art that the boxes of Fig. 2 further comprise the electronic controller components to deliver the control signals mentioned.

[0032] Numeral 40 is used to define the weight of e. g. a human subject to use the treadmill for which the device for adjusting the height of and the relief force acting on said weight 40 is provided. A position sensor 34 (not shown in Fig. 1) measures x_{real} and outputs $x_{measured}$. The force sensor 27 measures F_{real} and outputs $F_{measured}$. The (static) position of the cable $x_{measured}$ is input to the winch controller 35, acting via a control signal I_{winch} on the winch 10 to define the predetermined height, which can be input to the winch controller 35 via a key means or an electronic signal of said electronic control unit comprising the walking program for a patient.

[0033] The key means or an electronic signal of said electronic control unit comprising the walking program for a patient generates the input $F_{desired}$. A mixer 36 is provided to output the difference signal of $F_{desired}$ and $F_{measured}$. Said difference signal F_{diff} is input to a force controller 37 outputting the corresponding control signal I_{drive} which is fed to the actuator 26 to dynamically change the length of the cable 13 to control the force relief.

[0034] $F_{desired}$ is also the input to the spring load controller 38, outputting a signal $I_{springs}$ to bias means 31, which in turn moves bottom plate 24 to adjust the static weight compensation by springs 22. The length of the springs 22 is controlled with the bias means 31 to move the bottom plate 24 into a position that the tension of the springs 22 is such that patient is unloaded approximately by the desired force $F_{desired}$. The spring load controller 38 has therefore a far slower response than the force controller 37.

Claims

1. A device for adjusting the height of and the relief force acting on a weight (40), especially on the weight of a patient within a locomotion training means to be used for walking therapy of paraparetic or hemiparetic patients, wherein said weight is supported by a cable (11, 30), with a first cable length adjustment means (1) to provide an adjustment of the length of the cable (11) to define the height (x) of said suspended weight (40), with a second cable length adjustment means (2) to provide an adjustment of the length of the cable (11) to define the relief force (F) acting on the suspended weight (40).

2. The device according to claim 1, **characterized in that** the first cable length adjustment means (1) comprises a winch means (10) provided at one free end of the cable (11) or comprises a movable roller means (12, 14) provided upstream or downstream to the engagement point of the second cable length adjustment means (2) or comprises a displacement means for the second cable length adjustment means (2).

3. The device according to claim 1 or claim 2, **characterized in that** the second cable length adjustment means (2) comprises an elastic means (22) to provide a counter force to the suspended weight with a value in the range of the intended relief force.

4. The device according to claim 3, **characterized in that** a bias means (31) is connected in parallel to

the elastic means (22) to preadjust the value of the counter force.

5. The device according to claim 3 or 4, **characterized in that** the device furthermore comprises an actuator (26) providing a force parallel to the direction of the counter force provided by the elastic means (22), wherein the addition of the two forces determine the value of the intended relief force.

6. The device according to claim 5, **characterized in that** it further comprises a force transducer (27) connected to a control unit connected to said actuator (26) to control the relief force, preferably forming a closed loop control unit.

7. The device according to claim 6, **characterized in that** the bias means (31) is mounted in parallel with the actuator (26).

8. A process to adjust the conditions of a weight relieved walking for a patient, wherein said patient (40) is suspended with help of a cable (11) supported means, **characterized in that**

   - data relating to the height (x) of the patient and the intended relief force ($F_{desired}$) are entered in a control unit (35, 37, 38),
   - the control unit (35, 37, 38) activates a first cable length adjustment means (1) to provide an adjustment of the length of the cable (11) to define the height (x) of said suspended weight (40), and
   - the control unit activates a second cable length adjustment means (2) to provide an adjustment of the length of the cable (11) to define the relief force (F) acting on the suspended weight (40).

9. The process according to claim 8, wherein a force transducer (27) mounted in series to elastic means (22) of second cable length adjustment means (2) generates force measurement value of the supported weight and transmits said values to the control unit being connected with an actuator (26) of second cable length adjustment means (2), wherein the control unit controls the actuator (26) to provide a force parallel to the direction of the counter force provided by the elastic means (22), wherein the addition of the two forces determine the value of the intended relief force at every moment.

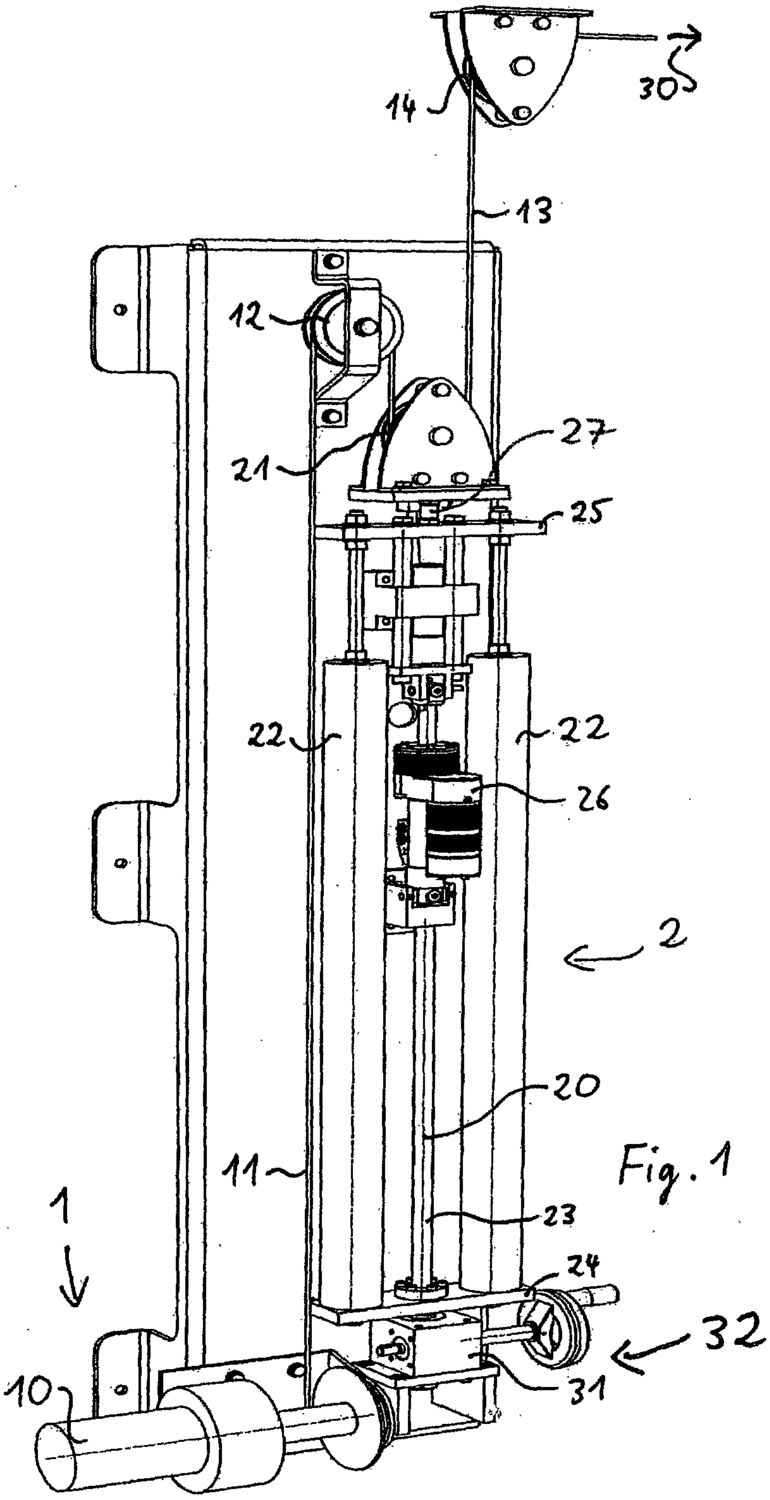
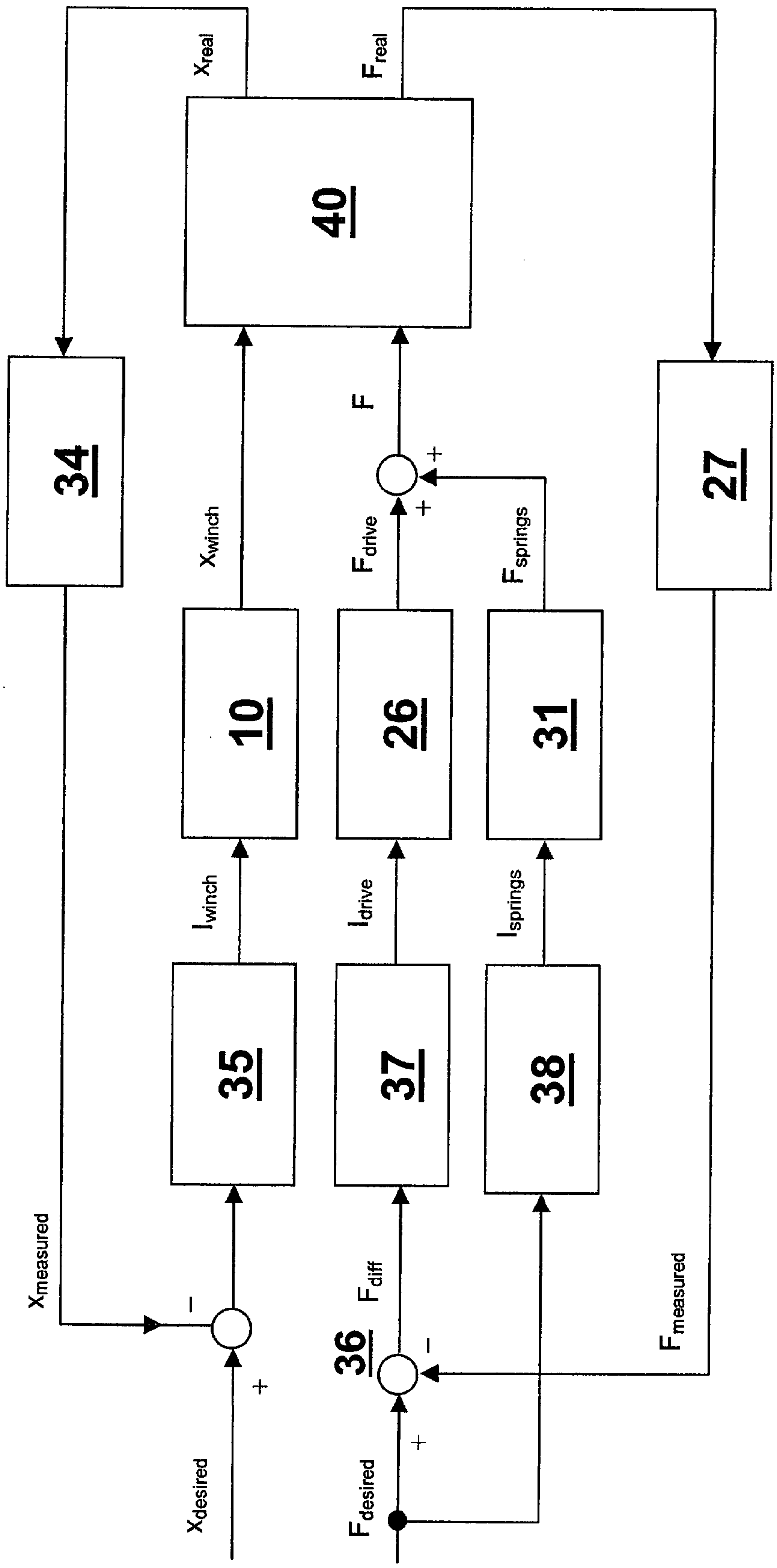


Fig. 1


X_real
F_real
40
34
27
F
X_winch
F_drive
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10
26
31
I_winch
I_drive
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35
37
38
X_measured
F_diff
36
F_measured
X_desired
F_desired

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 04 40 5236

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 273 502 A (KELSEY DOUGLAS ET AL) 28 December 1993 (1993-12-28) * column 3, line 16 - column 5, line 23; figures 1,2 *	1-4,8	A61H3/00 A63B69/00
X	WO 96/09094 A (TRANAS ROSTFRIA AB ;SOEDERLUND BENGT PATRIK (SE)) 28 March 1996 (1996-03-28)	1-4	
Y	* page 4, line 32 - page 6, line 35; figures 1,2 *	8,9	
Y	WO 01/28486 A (ROGOZINSKI JOSEPH) 26 April 2001 (2001-04-26) * page 7, line 25 - page 8, line 5; figure 12A *	8,9	
Y	US 2002/065173 A1 (COOK GERRY) 30 May 2002 (2002-05-30) * paragraph [0021] - paragraph [0028]; figures 1-4 *	8	
A	WO 03/035184 A (UNIV CALIFORNIA) 1 May 2003 (2003-05-01) * abstract; figure 1 *	1-9	TECHNICAL FIELDS SEARCHED (Int.Cl.7) A61H A63B A61G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	9 September 2004	Jekabsons, A

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CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

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