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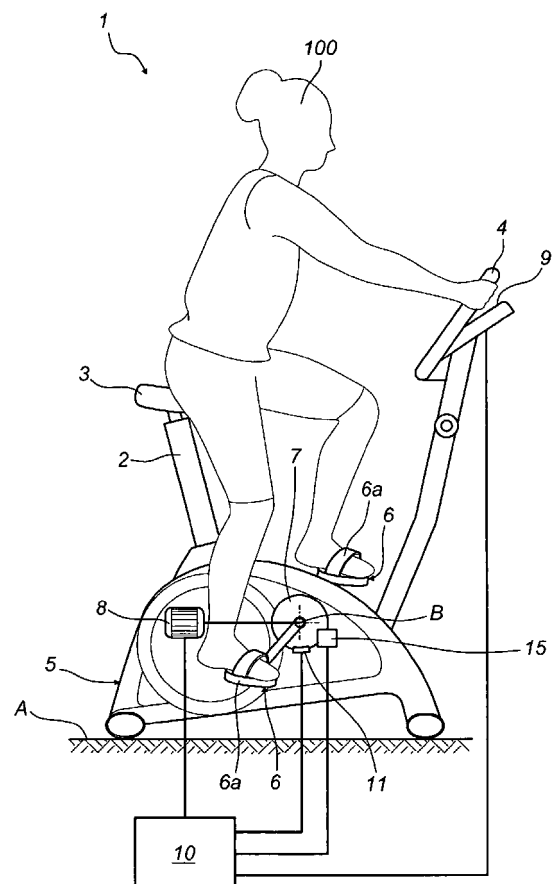
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(54) **Exercise machine and method for performing an exercise**

(57) A exercise machine comprises a frame (2), a hand or foot support element (6) for a user (100), rotatably connected to the frame (2), an electric motor (8) connected to the support element (6) to set the latter in rotation relative to the frame (2), and a brake (11) configured to be operatively applied to the support element (6). The machine also comprises a control unit (10) connected to the electric motor and to the brake (11) in order to drive them and an interface (9) connected to the control unit (10) and configured to allow the user (100) to select a first, active exercising mode and a second exercising mode where the motor (8) delivers a drive torque to move the support element (6) at a predetermined speed and in a predetermined direction as a function of a reference value set by the user (100) for the rotation speed of the support element (6). The interface (9) is configured to set a maximum value for the drive torque deliverable by the electric motor (8) during the exercise and the control unit (10) is programmed to drive the electric motor (8) during the exercise in order to vary the torque it delivers, within the limit of the maximum value set by the user (100), according to the action applied by the user (100) to the support element (6) and so as to keep the rotation speed of the support element (6) close to the set reference value irrespective of the direction of the action applied by the user (100).

**FIG. 1**



## Description

**[0001]** This invention relates to an exercise machine and a method for performing an exercise, preferably using such machine.

**[0002]** The invention is applicable in particular in the fitness trade and in the field of gym equipment. Known in the prior art are exercise machines comprising a frame and a support element which is cyclically movable to exchange power with a user during an exercise.

**[0003]** The exercise machines concerned are typically stationary bikes (standard or reclining type) or seatless exercise stations which can be used from a wheelchair or the like.

**[0004]** In light of this, the support elements are usually pedals, for exercising and training the lower limbs, or handgrips, for training the upper limbs. Prior art exercise machines are equipped with a pedal or handgrip drive system which can be selectively switched (automatically or by means of a user control) from a torque generating configuration, where it delivers drive torque used to rotate the pedals in a predetermined direction, to a brake configuration, where it opposes the rotation of the pedals imparted by the user.

**[0005]** In the jargon of the trade, the torque generating and brake configurations define a "passive" and an "active" configuration of the exercise machine, respectively.

**[0006]** It should be noted, however, that the terms "active" and "passive" refer to the user and not to the machine. Thus, in the active configuration, it is the user who generates movement, or at least contributes to generating the movement, whereas in the passive configuration it is the machine which drives the user's movements, mainly for mobility therapy or rehabilitation purposes.

**[0007]** Described below are some prior art exercise machines capable of operating in both an active and a passive configuration.

**[0008]** Patent application WO2011042813 describes an active/passive bike where an algorithm is used to control the intensity of an exercise in real time, based on at least one of the following factors: heart rate, rotation speed, torque/power generated by the user, torque/power delivered (generated) by the motor.

**[0009]** Document WO9717932 also describes an active/passive exercise device for the lower and upper limbs. The device comprises a disc, rotatably coupled to a frame, and two hand or foot supports coupled to the disc. A motor is connected to the disc in order to rotate the disc when the device is in the passive mode. The device also comprises a control unit which is configured to allow the user to adjust the speed of the disc in the passive mode and to adjust the resistance to disc movement in the active mode. More specifically, the device described in that document can automatically switch from active mode to passive mode according to the force which the user applies to the supports, for example switching from the passive mode to the active mode as soon as the user applies resistance to the rotation of the supports

themselves.

**[0010]** Disadvantageously, prior art exercise machines and devices are not very versatile and cannot meet the needs both of a user (patient) undergoing rehabilitation and those of a user (athlete) undergoing training.

**[0011]** This invention has for an aim to provide an exercise machine and a method for performing an exercise which overcome the above mentioned disadvantages of the prior art.

**[0012]** More specifically, the aim of this invention is to provide a comprehensive and versatile exercise machine.

**[0013]** Another aim of the invention is to provide an exercise machine capable of automatically adapting to the needs of a patient undergoing rehabilitation.

**[0014]** Another aim of the invention is to provide an exercise machine which can offer the user a multiplicity of exercises and activities.

**[0015]** These aims are fully achieved by the exercise machine according to the invention, comprising a frame, at least one hand or foot support element for a user, rotatably connected to the frame to move cyclically and exchange power with the user during an exercise, an electric motor connected to the support element to set the latter in rotation relative to the frame, a brake configured to be operatively applied to the support element to slow its rotation, a control unit connected to the electric motor and to the brake in order to drive them and an interface connected to the control unit and configured to set (offer) at least one first, exercising mode, where the user moves the support element by overcoming the action of the brake, and at least one second exercising mode where the motor delivers a drive torque to move the support element at a predetermined speed and in a predetermined direction as a function of a reference value set by the user for the rotation speed of the support element.

**[0016]** The control unit is programmed to control the drive torque during the exercise in such a way as to vary the delivered torque as a function of an action applied by the user to the support element, so as to keep the rotation speed of the support element close to the set reference value irrespective of the direction of the action applied by the user. Thus, when the user acts on the support element in the same direction as the preset rotation direction, the torque delivered by the electric motor decreases, and when the user acts on the support element in the opposite direction to the preset rotation direction, the torque delivered by the electric motor increases, the increase in the delivered torque being limited to reaching the set maximum value.

**[0017]** Preferably, the machine comprises two support elements, in the form of pedals, which rotate as one about an axis of rotation (equidistant therefrom).

**[0018]** Alternatively, or in addition, the supports might be in the form of handgrips or handles, to allow training of the user's upper limbs.

**[0019]** The exercise machine is thus configured to allow the user to perform either isokinetic or eccentric exercises, with the possibility of setting the maximum drive torque deliverable by the motor, so that the machine can be used appropriately both by a user (patient) undergoing rehabilitation and a user (athlete) undergoing intensive training.

**[0020]** An exercise is defined as "isokinetic" if the angular velocity of the movement remains constant and the resistance which the machine opposes to the movement or the force it applies is a function of the force which the user produces during the movement.

**[0021]** On the other hand, an exercise is defined as "eccentric" if it involves a particular type of muscle activation whereby the muscle produces power by extension, instead of contraction as in concentric work.

**[0022]** These and other features of the invention will become more apparent from the following detailed description of a preferred embodiment of the exercise machine illustrated by way of example in the accompanying drawings, in which:

- Figure 1 is a schematic side view of an exercise machine according to this invention;
- Figure 2 schematically represents the control unit of the exercise machine of Figure 1;
- Figure 3 shows a flow diagram representing a control logic of the exercise machine of Figure 1 in an adaptive control mode;
- Figure 4 represents data acquisition relating to the drive torque over time.

**[0023]** The exercise machine 1 comprises a frame 2 designed to support the machine 1 on a supporting surface "A", typically the ground or the floor of a gym. Preferably, the frame 2 comprises a seat 3 for a user 100 and at least one handle portion 4, or handgrip, placed at a distance from the seat 3 such as to allow the user to keep a secure hold on it. In a first embodiment, the seat 3 is substantially in the form of a bicycle saddle and the handle portion 4 is located in front of the seat 3 and is in the form of a handlebar, like that of a bicycle. In other words, in the first embodiment of it, the exercise machine 1 is substantially a fitness bicycle or exercise bike.

**[0024]** In a second embodiment (not illustrated), on the other hand, the seat is chair-like and the handle portion is defined by a pair of handgrips mounted laterally of the seat.

**[0025]** It should be noted that in the second embodiment, the machine 1 might comprise a pair of handle portions, one in the form of a handlebar and one in the form of a handgrip. In other words, in the second embodiment of it, the exercise machine 1 is substantially a reclining exercise bike. Alternatively, the machine might be a seatless exercise station which allows the user to access the station with a wheelchair or the like.

**[0026]** The machine 1 also comprises at least one movement unit 5 designed to interact with the user 100

during an exercise.

**[0027]** More precisely the machine 1 (and more specifically, the movement unit 5) comprises a hand or foot support element 6 for the user 100, rotatably connected to the frame 2 to move cyclically and exchange power with the user 100 during an exercise.

**[0028]** Preferably, the machine 1 comprises two support elements 6 located on opposite sides of the frame 2 and rotatable as one about the same axis of rotation "B".

**[0029]** Preferably, the support elements 6 are in the form of pedals 6a and are located at a height below (or, at most, aligned with) the seat 3.

**[0030]** Alternatively, the support elements might be in the form of handles and be placed at a height above the seat 3 to allow the user 100 to train the upper limbs.

**[0031]** Preferably, the movement unit 5 comprises a flywheel 7 which is rotatably associated with the frame 2 and to which the support elements 6 (that is, the pedals 6a) are rigidly connected. Preferably, the flywheel 7 is connected to an electric motor 8 configured to set the latter in rotation about the axis of rotation "B", in such a way as to rotate the support elements 6.

**[0032]** In other words, the machine 1 comprises an electric motor 8 connected (through the agency of the flywheel 7) to each support element 6 in order to set it in rotation relative to the frame 2 in a predetermined direction of rotation.

**[0033]** In an alternative embodiment, the flywheel might be mounted on the frame on the same shaft as the motor and coupled to the axis of rotation of the pedals by a mechanical transmission.

**[0034]** Preferably, the motor 8 can be switched to rotate in both directions as a function, for example, of a setting of the user 100, or automatically, as explained in more detail below.

**[0035]** Preferably, the machine 1 also comprises a brake 11 operating on the support element 6 and, more precisely, connected to the flywheel 7 to prevent or allow its rotation.

**[0036]** The brake 11 may be driven as a function, for example, of a setting of the user 100, or automatically.

**[0037]** Alternatively, the brake 11 may be activated manually by the user 100, by means of a specific control or lever (not illustrated) mounted on the machine (on the frame 2 or, preferably, at the handle portion 4). Preferably, the brake 11 is an electromagnetic brake and comprises, for example, a copper disc coupled to the frame rotatably as one with the flywheel and an electromagnet mounted on the frame at a peripheral portion of the copper disc.

**[0038]** To control the electric motor 8 and/or the brake 11, the exercise machine 1 comprises a control unit 10.

**[0039]** The control unit 10 has a first and a second operating configuration.

**[0040]** In the first operating configuration, the control unit 10 allows the user 100 to perform an exercise in a first, active mode, where the user 100 moves the support element by overcoming the action of the brake 11.

**[0041]** In the second operating configuration, the control unit 10 allows the user to perform an exercise in a second exercising mode, including different types of activities.

**[0042]** These activities are connected mainly with a plurality of data relating to the user 100. For example, the data may be provided by the user 100 before or during the exercise.

**[0043]** In this regard, the exercise machine 1 also comprises an interface 9 connected to the control unit 10 and configured to allow the user 100 to interact with the exercise machine 1 itself by setting parameters and/or displaying data relating to the exercise and/or to the machine's state of operation.

**[0044]** Preferably, the interface 9 is located at the handle portion 4 of the frame 2.

**[0045]** In the example illustrated, the interface 9 is mounted on a central crossbar of the handlebar so that the user 100 can see and access it easily (although other configurations are possible).

**[0046]** The interface 9 comprises a screen 9a and a control panel, which may be a keyboard separate from the screen 9a. More preferably, the interface 9 is at least partly defined by a touch screen comprising both.

**[0047]** Whatever the case, it should be stressed that the term "interface", as used in this text, denotes any device or element (whether hardware or software) which allows an exchange of data/information between the user 100 and the machine 1, as for example, the user's personal data (age, weight, height, sex ...) or information about the exercise to be performed, etc.

**[0048]** Obviously, the exercise machine can operate in manual mode, based on the commands selected by the user or by personnel in charge (operator) using the interface 9 (control panel or touch screen), or in automatic mode, based on predefined programs adapted and customized by the operator according to the needs of different users. These predefined programs may reside in a memory unit (not illustrated) mounted on the exercise machine or any other medium (for example, a USB flash drive, a remote server connected by wired or wireless means with the exercise machine, etc.) and may be downloaded to the exercise machine. For example, before the exercise, the user may log in through the interface 9, by entering a numeric code or username stored on a portable medium, after which the user's personal program is loaded to the control unit.

**[0049]** The considerations hereinafter made to manual operation can also apply to automatic operation. The interface 9 is configured to allow the user 100 to enter (for example using a data entry form 9b) information useful for the performance of the exercise, that is to say, exercise parameters and values.

**[0050]** The interface 9 is also configured to allow the user 100 to select the first exercising mode, where the user 100 moves the support element by overcoming the action of the brake 11, and the second exercising mode where the motor 8 delivers a drive torque to move the

support element 6 at a predetermined speed and in a predetermined direction as a function of a reference value " $V_{ref}$ " set through the interface 9 by the user 100 for the rotation speed of the support element 6.

**[0051]** Still more preferably, the interface 9 is also configured to allow the user 100 to set a maximum value " $C_{max}$ " for the drive torque deliverable by the electric motor 8 during the exercise and to adjust this value in such a way as to vary the difficulty of the exercise and/or limit the effort required for it.

**[0052]** In the case of manual operation, both the speed reference value " $V_{ref}$ " and the maximum torque value " $C_{max}$ " are preferably entered by the user 100 through the data entry form 9b of the interface 9. Alternatively, in the case of automatic operation, the control unit 10 runs the above described first exercising mode or second exercising mode based on a customized program defined by the operator in which the " $V_{ref}$ " and " $C_{max}$ " values can also be set according to the user's needs, with the possibility of further modifying them in such a way as to take into account the progress and results achieved during previous training sessions.

**[0053]** Whatever the case, the control unit 10 is thus configured/programmed to control the electric motor 8 and/or the brake 11, as explained in more detail below, as a function of the reference value " $V_{ref}$ " set by the user 100 through the interface 9 or received automatically on the basis of the customized exercise and/or of the interaction of the user 100 with the support elements 6. Preferably, the control unit 10 is connected to both the brake 11 and the electric motor 8 to drive them in combination (alternately) as a function of a manually set program, or a customized program and/or of the behaviour of the user 100 during the exercise.

**[0054]** In one possible embodiment, the control unit comprises both a drive card for the motor 8 and a drive card for the brake 11.

**[0055]** Thus in the second exercising configuration, the control unit 10 allows the user to perform an exercise in a second exercising mode, including different types of activities.

**[0056]** Advantageously, one of these activities is of the type referred to as "isokinetic" and is described below.

**[0057]** In the isokinetic control mode, the control unit 10 is programmed to keep the rotation speed of the support elements 6 equal to the value of " $V_{ref}$ " during the entire duration of the exercise, where " $V_{ref}$ " was set previously either manually or automatically, as described above. Also, the reference value " $V_{ref}$ " may be modified by the user 100 with the interface 9 during the exercise. Similarly, besides the value " $V_{ref}$ ", the maximum value " $C_{max}$ " of the drive torque delivered by the motor 8, is supplied to the control unit 10, and may be modified during the exercise using the interface 9 (more specifically, using a specific adjuster element 12 preferably forming part of the touch screen).

**[0058]** Thus, the control unit 10 is programmed to drive the electric motor 8 in such a way that the motor delivers

the correct drive torque during the exercise, that is to say, the torque needed to reach the reference value " $V_{ref}$ " of the rotation speed of the support elements 6.

**[0059]** More specifically, the control unit 10 is programmed to allow the drive torque of the electric motor 8 to be varied during the exercise in order to keep the rotation speed of the support element 6 (that is, of the flywheel 7) close to the reference value " $V_{ref}$ " set by the user 100.

**[0060]** That way, when the user 100 acts on the support element 6 in the same direction as the preset rotation direction, the drive torque generated by the electric motor 8 decreases.

**[0061]** On the contrary, the control unit 10 drives the motor 8 and varies its drive torque in such a way that when the user 100 acts on the support element 6 in the opposite direction to the preset rotation direction, the torque delivered by the electric motor 8 increases.

**[0062]** In other words, the control unit 10 is programmed to drive the motor 8 according to the action of the user 100 on the support elements 6 in order to keep the rotatable support elements 6 at a speed equal to the reference value " $V_{ref}$ " in the predetermined direction.

**[0063]** It should be noted that increasing the drive torque is limited to reaching the maximum value " $C_{max}$ " set by the user 100 with the interface 9 or received automatically based on the customized exercise.

**[0064]** It should be noted that the maximum value " $C_{max}$ " of the drive torque is selectable within a defined interval between a minimum value which is preset as a function of machine inertia correlated with the support element 6 and an estimated weight for the arms and legs of the user 100, and an upper safety value.

**[0065]** In order to allow the delivered torque and the rotation speed of the support elements 6 to be measured, the machine 1 comprises suitable sensors 15 associated with the support elements (more specifically, with the flywheel 7) and with the motor 8.

**[0066]** More precisely, the machine 1 comprises a Hall sensor, an encoder or the like, associated with the flywheel 7 in order to measure the rotation speed thereof and/or to determine its angular position. Preferably, the control unit 10 is equipped with a module for measuring the (instantaneous) torque delivered by the motor 8 during operation, for example by means of a torque sensor (for example, a torque meter).

**[0067]** In addition, or alternatively, the torque might be measured indirectly (without using specific sensors) by measuring the current absorbed by the motor.

**[0068]** In use, once the rotation direction, the speed reference value " $V_{ref}$ " and the maximum drive torque value " $C_{max}$ " have been made available to it, whether manually or automatically, the control unit 10 acts on the motor to rotate the flywheel 7.

**[0069]** If the user 100 applies a braking action on the support elements 6, the control unit 10 increases the drive torque delivered by the motor in order to overcome the resistance and follow the speed reference value " $V_{ref}$ ".

**[0070]** If the user 100 contributes to rotating the support elements 6 in the predetermined direction, the control unit 10 decreases the drive torque delivered by the motor in such a way as to assist the user 100 by providing only the torque needed to reach the reference speed.

**[0071]** It should be noted that the control unit 10 preferably has a control logic (implemented by a specific code or software) where gain is limited in such a way as not to cause sudden variations in the torque curve of the motor 8, thereby safeguarding the user.

**[0072]** The control unit 10 is configured to activate the brake 11 when the drive torque generated by the electric motor 8 is cancelled so as to keep the rotation speed of the support elements 6 close to the reference value " $V_{ref}$ ".

**[0073]** Thus, the control unit 10 is programmed to activate the brake 11 only after the motor 8 receives a "shut-down", or run idle, command imparted to the motor 8 by the selfsame control unit 10 when the user 100 is capable, unassisted, of generating enough torque to rotate the support elements 6 at a speed equal to the reference value " $V_{ref}$ ".

**[0074]** In other words, the control unit 10 is configured to activate the brake 11 when the user 100 generates work (delivers torque) which can move the support elements 6 at a speed greater than the reference speed without any assistance from the electric motor 8.

**[0075]** Advantageously, that way, the machine 1 allows the user to perform an active exercise even when the control unit 10 is in the second operating configuration.

**[0076]** In an alternative embodiment (not illustrated), the control unit is configured to drive the electric motor both as a generator and as a brake, without the need for a brake to be applied to the flywheel. That way, the control unit drives only the motor and does not need to be connected to other "working" parts.

**[0077]** Preferably, the second exercising mode also allows a type of activity that may be defined as "adaptive", described below.

**[0078]** Thus, in the second operating configuration, the control unit 10 is switchable between the isokinetic control mode and the adaptive control mode.

**[0079]** In this regard, the interface 9 is preferably configured in such a way as to allow the user to select isokinetic control mode or adaptive control mode.

**[0080]** The term "adaptive" is used to mean a control mode where the machine 1 assists the user by adapting to his/her needs (capabilities).

**[0081]** In the adaptive control mode, the control unit 10 is configured to be able to automatically vary the speed reference value " $V_{ref}$ ", set by the user 100, as a function of the behaviour of the selfsame user 100 during a preset time interval.

**[0082]** More precisely, the control unit 10 comprises a timer configured to discretize an exercise time into a plurality of time intervals ( $\Delta T$ ) of preset duration.

**[0083]** The control unit 10 is configured to be able, in each time interval, to automatically vary the speed refer-

ence value " $V_{ref}$ ", set by the user 100, as a function of the behaviour of the selfsame user 100 during the preceding time interval.

**[0084]** It should be noted that within each time interval " $\Delta T$ " the control unit operates substantially in the isokinetic mode, varying the parameters only at the end of the time interval.

**[0085]** It should be noted, however, that in the adaptive mode, the brake is disabled even when the torque is cancelled.

**[0086]** At the end of (or within) each time interval, the control unit 10 performs a test (or two or more tests) correlated with the user's behaviour during the exercise and, as a function of the data found, varies or leaves unchanged the reference speed but, between one test and the next, behaves in substantially isokinetic mode.

**[0087]** More precisely, each time interval " $\Delta T$ " is divided into a first sub-interval " $\Delta T1$ " and a second sub-interval " $\Delta T2$ ".

**[0088]** Preferably, the control unit 10 is programmed to test the rotation speed of the support element 6 in the first sub-interval " $\Delta T1$ " and to test the drive torque delivered by the electric motor 8 in the second sub-interval " $\Delta T2$ ".

**[0089]** In the preferred embodiment, the test whether the speed reference value " $V_{ref}$ " has been exceeded and the test whether the torque limit value has been exceeded are performed in two immediately successive sub-intervals of time.

**[0090]** That way, the torque test serves as a control for the speed test, so as to allow the control unit 10 to detect whether the user responds to a speed increase with unwanted stiffening.

**[0091]** It should be noted, however, that using the expressions "first sub-interval" and "second sub-interval" does not necessarily mean giving a connotation of time to the succession of the two sub-intervals.

**[0092]** In effect, in alternative embodiments, the control unit might perform the torque test before or after the speed test. That means the first sub-interval might come before or after the second sub-interval. In order to perform the above mentioned tests, the control unit 10 is set up to measure the (instantaneous) rotation speed value " $V_i$ " of the support element 6 (that is, of the flywheel 7) and programmed to compare the measured value with the speed reference value " $V_{ref}$ " at each time interval " $\Delta T$ ".

**[0093]** Further, the control unit 10 is configured to increase the speed reference value " $V_{ref}$ " according to the comparison.

**[0094]** More specifically, the control unit 10 increases the value when the difference between the measured speed value " $V_i$ " and the reference speed value " $V_{ref}$ " is greater than a preset quantity.

**[0095]** In other words, if the user 100 can move the support elements 6 at a speed which exceeds the reference speed at least by the preset quantity, the control unit 10 increases the reference speed itself by a prede-

termined quantity (which might be equal to the preset quantity).

**[0096]** Thus, in the adaptive control mode, the control unit 10 follows the will (and the ability) of the user 100 to increase the difficulty of the exercise.

**[0097]** In use, the control unit 10 increases the rotation speed reference value " $V_{ref}$ " when the drive torque required of the motor 8 to move the support elements 6 at the reference speed falls below a certain threshold, which may be equal or slightly greater than zero.

**[0098]** In other words, in the adaptive control mode, the brake 11 does not come into operation (that is to say, the control unit 10 does not activate it). Further, the control unit 10 is configured to assess the ability of the user 100 to follow the movement of the support elements 6 at the reference speed (that is, the reference value).

**[0099]** Thus, the control unit 10 is set up to receive a signal representing a value of the (instantaneous) drive torque " $C_i$ " delivered by the electric motor 8 and programmed to compare that value with a preset drive torque limit value " $C_{lim}$ " at each time interval " $\Delta T$ ".

**[0100]** The limit value " $C_{lim}$ " preferably corresponds to the drive torque needed to overcome the force to set the mechanism in motion (at the reference speed " $V_{ref}$ "), including the weight of the pedals and the weight of a user's legs or arms, with which the user's contribution (which may be negative or positive) is associated.

**[0101]** That way, the control unit 10 detects an increase in the drive torque when the user 100 strains to remain at the reference speed.

**[0102]** In light of this, the control unit 10 is configured to reduce the reference speed when the instantaneous torque is greater than the aforementioned limit value " $C_{lim}$ ".

**[0103]** Preferably, the control unit 10 is configured to update the drive torque limit value " $C_{lim}$ " each time the rotation speed reference value " $V_{ref}$ " of the support elements 6 is updated (that is, varied). Thus, the torque limit value " $C_{lim}$ " is associated with the speed reference value " $V_{ref}$ ".

**[0104]** An increase in the speed reference value " $V_{ref}$ " corresponds to an increase in the torque limit value " $C_{lim}$ " (and vice versa).

**[0105]** That way, the machine 1 is constantly calibrated to values correlated with the real capabilities of the user 100.

**[0106]** Thus, the control unit 10 is able to assess whether the user 100 is capable of moving faster than initially set with the interface 9, adapting the difficulty of the exercise accordingly.

**[0107]** This is particularly important for rehabilitation, because the user 100 might not know how his/her limb will respond to a predetermined stress (that is, to a movement at the reference speed). Advantageously, thanks to the adaptive control mode, it is the exercise machine 1 itself which "assesses" whether or not the user 100 needs or wants to increase the difficulty of the mobility therapy exercise.

**[0108]** Preferably, the control unit 10 is programmed to apply discrete variations to the rotation speed, incrementing or decrementing it by the same quantity.

**[0109]** In effect, the control unit 10 is configured to increase or decrease the speed reference value " $V_{ref}$ " by a preset quantity (the same as the one used for the speed test) even when the difference between the measured speed value and the reference value " $V_{ref}$ " is greater than the preset quantity. Hence, if the real speed of the support elements 6 is much greater than the reference speed, two successive time intervals may be necessary for the increment imparted by the control unit 10 to take the reference value " $V_{ref}$ " to a value compatible with the requirements of the user 100.

**[0110]** In other words, the speed reference value " $V_{ref}$ " is varied over time by a step function.

**[0111]** That way, the exercise machine 1 follows the mobility capabilities of the user 100 without imparting speed (and hence torque) variations which are too sudden.

**[0112]** Advantageously, in the adaptive control mode, the machine 1, by automatically assessing the conditions of the user 100, increases the difficulty of the exercise if the user 100 underestimates his/her own capabilities (by setting too low a reference speed) or decreases the difficulty if his/her own capabilities are overestimated (by setting too high a reference speed).

**[0113]** It should be noted that even in the adaptive control mode, it is possible to set the drive torque saturation value.

**[0114]** In that case, the control unit 10 is programmable to stop the electric motor 8 in the event of a sudden, excessive increase in the drive torque, above the maximum value " $C_{max}$ ", typically indicative of spasms or pain.

**[0115]** Advantageously, this makes it possible to minimize the possibility of injury to the user 100 during an exercise.

**[0116]** Also, it should be noted that by setting a relatively high drive torque limit value " $C_{lim}$ " the user 100 can perform an exercise of eccentric type even without switching the control unit 10 from the second mode (adaptive) to the first mode (isokinetic).

**[0117]** Hence, the interface 9 (preferably through the drive torque adjustment element 12) allows the user 100 to pass rapidly from an exercise of adaptive type, and hence typically for mobility rehabilitation, to an exercise of eccentric type, and hence for strength training, without resetting the machine 1 by resetting the control unit 10. This invention also has for an object a method for controlling the exercise machine 1 comprising the frame 2, the hand or foot support element 6 for the user 100, rotatably connected to the frame 2, the electric motor 8 connected to the support element 6 to set the latter in rotation and the brake 11 configured to be operatively applied to the support element.

**[0118]** It should be noted that all the consideration made with regard to the machine apply fully also to the steps in the method described below since the exercise

machine 1 is programmed to implement the method.

**[0119]** The method comprises the steps of offering to the user 100, through an interface 9, the possibility of setting at least a first exercising mode, where the user 100 moves the support element 6 by overcoming the action of the brake 11, and a second exercising mode where the motor 8 delivers a drive torque to move the support element 6 at a predetermined speed and in a predetermined direction as a function of a reference value ( $V_{ref}$ ) for the rotation speed of the support element 6 set by the user 100 or automatically through specific hardware or software media.

**[0120]** In the second exercising mode, the method comprises a step of setting the drive torque deliverable by the motor 8 during the exercise as a function of a maximum value " $C_{max}$ " set using the interface 9.

**[0121]** In other words, the method comprises a step of setting a torque value above which the motor 8 cannot operate.

**[0122]** Next, the motor 8 is started by a control unit 10 with a drive torque equal to that necessary to move the support element 6 at a speed equal to the predefined value and in the predetermined direction of rotation.

**[0123]** Through the agency of specific sensors 15, the control unit 10 detects the action of the user 100 on the support element 6 during the rotation of the support element 6 itself and accordingly drives the electric motor 8 in such a way as to vary its delivered torque as a function of the detected action, in order to keep the rotation speed of the support element 6 close to the set reference value " $V_{ref}$ " irrespective of the direction of the action applied by the user 100.

**[0124]** Thus, when the user 100 acts on the support element 6 in the same direction as the preset rotation direction, the torque delivered by the electric motor 8 decreases, and when the user 100 acts on the support element 6 in the opposite direction to the preset rotation direction, the torque delivered by the electric motor 8 increases.

**[0125]** It should be noted, as already stated in connection with the machine 1, that increasing the drive torque is limited to reaching the set maximum value " $C_{max}$ ".

**[0126]** Similarly to what has been stated previously, the method comprises a step of activating the brake 11, through the control unit 10 when the drive torque generated by the electric motor 8 is zero, in response to an action applied by the user to the support element 6 in the same direction as the preset rotation direction tending to increase the rotation speed of the support element, in order to keep the rotation speed of the support element 6 close to the set reference value " $V_{ref}$ ".

**[0127]** In the second exercising mode, the user 100 has the possibility of setting an adaptive control mode for the machine 1.

**[0128]** The adaptive control mode comprises a step of discretizing the exercise time " $T$ " (initially set by the user 100) into a plurality of time intervals " $\Delta T$ " of preset duration and a step of updating at each time interval " $\Delta T$ ",

through the control unit 10, the speed reference value " $V_{ref}$ " set by the user 100, with the possibility of increasing or decreasing it according to the behaviour of the user 100 during that time interval " $\Delta T$ " or a preceding time interval.

**[0129]** More specifically, in each time interval " $\Delta T$ " (in particular in a first sub-interval " $\Delta T_1$ ") the control unit 10 performs the following steps:

- measuring a value " $V_i$ " of the rotation speed of the support element 6;
- comparing the measured value " $V_i$ " with the reference value " $V_{ref}$ ";
- increasing the reference value " $V_{ref}$ " when the difference between the measured value " $V_i$ " and the reference value " $V_{ref}$ " is greater than a preset quantity.

**[0130]** After that, the control unit 10 is configured to update the torque limit value " $C_{lim}$ " as a function of the updated value of the speed reference " $V_{ref}$ ". In light of this, if the speed reference " $V_{ref}$ " is not modified, the torque limit value " $C_{lim}$ " also remains unchanged.

**[0131]** Furthermore, in each time interval " $\Delta T$ " (in particular in a second sub-interval " $\Delta T_2$ ") the control unit 10 performs the following steps:

- measuring the drive torque " $C_i$ " delivered by the electric motor 8;
- comparing the measured value " $C_i$ " with a preset limit value " $C_{lim}$ ";
- reducing the reference speed " $V_{ref}$ " when the measured torque " $C_i$ " is greater than the limit value " $C_{lim}$ ".

**[0132]** When the measured torque " $C_i$ " is less than (or equal to) the limit value " $C_{lim}$ ", the control unit 10 leaves the speed reference value " $V_{ref}$ " unchanged.

**[0133]** There is also another decision-making block for " $C_i$ " (after the block where " $C_i$ " is compared with " $C_{lim}$ "), where " $C_i$ " is compared with 0. If the measured torque " $C_i$ " has a value close to zero (as schematically represented in Figure 3), the control unit 10 is programmed to increase the speed reference " $V_{ref}$ " (preferably by a preset, discrete increment  $\Delta V$ ). Otherwise, " $V_{ref}$ " is left unchanged. It should be noted that the flow diagram of Figure 3 also shows:

- a block " $V_i$ ", indicating a measuring (or acquisition) block for the (instantaneous) speed value " $V_i$ ";
- a block " $C_i$ ", indicating a measuring (or acquisition) block for the (instantaneous) torque value " $C_i$ ".

**[0134]** The invention achieves the preset aims and brings important advantages.

**[0135]** In effect, the machine and control method according to the invention allow the user to perform a wide variety of activities, from exercises of isokinetic type to exercises of eccentric type.

**[0136]** Moreover, the possibility of controlling the max-

imum torque allows the machine to be used both by users undergoing rehabilitation and users who require training which involves great strain.

**[0137]** It should be noted that the possibility of activating the brake during operation in isokinetic control mode allows the user to perform an active exercise, a passive exercise and an eccentric exercise, in succession and in combination, without having to modify any parameter.

**[0138]** Particularly useful for rehabilitation purposes is the adaptive control mode, where the machine automatically "senses" the patient's state and accordingly avoids stress and strain that would be critical for the patient's conditions.

**[0139]** In effect, automatically updating the rotation speed of the support elements as a function of the behaviour of the user (patient) ensures that the exercise performed is suitable for the patient's physical conditions.

## Claims

1. An exercise machine comprising:

- a frame (2);
- at least one hand or foot support element (6) for a user (100), rotatably connected to the frame (2) to move cyclically and exchange power with the user (100) during an exercise;
- an electric motor (8) connected to the support element (6) to set the latter in rotation relative to the frame (2);
- a brake (11) configured to be operatively applied to the support element (6) to slow its rotation;
- a control unit (10) connected to the electric motor and to the brake (11) in order to drive them;
- an interface (9) connected to the control unit (10) to set at least one first exercising mode, where the user (100) moves the support element (6) by overcoming the action of the brake (11), and at least one second exercising mode where the motor (8) delivers a drive torque to move the support element (6) at a predetermined speed and in a predetermined direction as a function of a reference value ( $V_{ref}$ ) set by the user (100) for the rotation speed of the support element (6),

### characterized in that

the interface (9) is configured to set a maximum value ( $C_{max}$ ) for the drive torque deliverable by the electric motor (8) during the exercise, and in that the control unit (10) is programmed to drive the electric motor (8) during the exercise in order to vary the torque it delivers according to the action applied by the user (100) to the support element (6), so as to keep the rotation speed of the support element (6) close to the set reference value ( $V_{ref}$ ) irrespective of the direction of the action applied by the user (100), so



that an action applied by the user (100) to the support element (6) in the same direction as the preset rotation direction corresponds to a decrease in the drive torque delivered by the electric motor (8), and an action applied by the user (100) to the support element (6) in the direction opposite to the preset rotation direction corresponds to an increase in the drive torque delivered by the electric motor (8), the increase in the drive torque being limited to reaching the set maximum value ( $C_{\max}$ ).

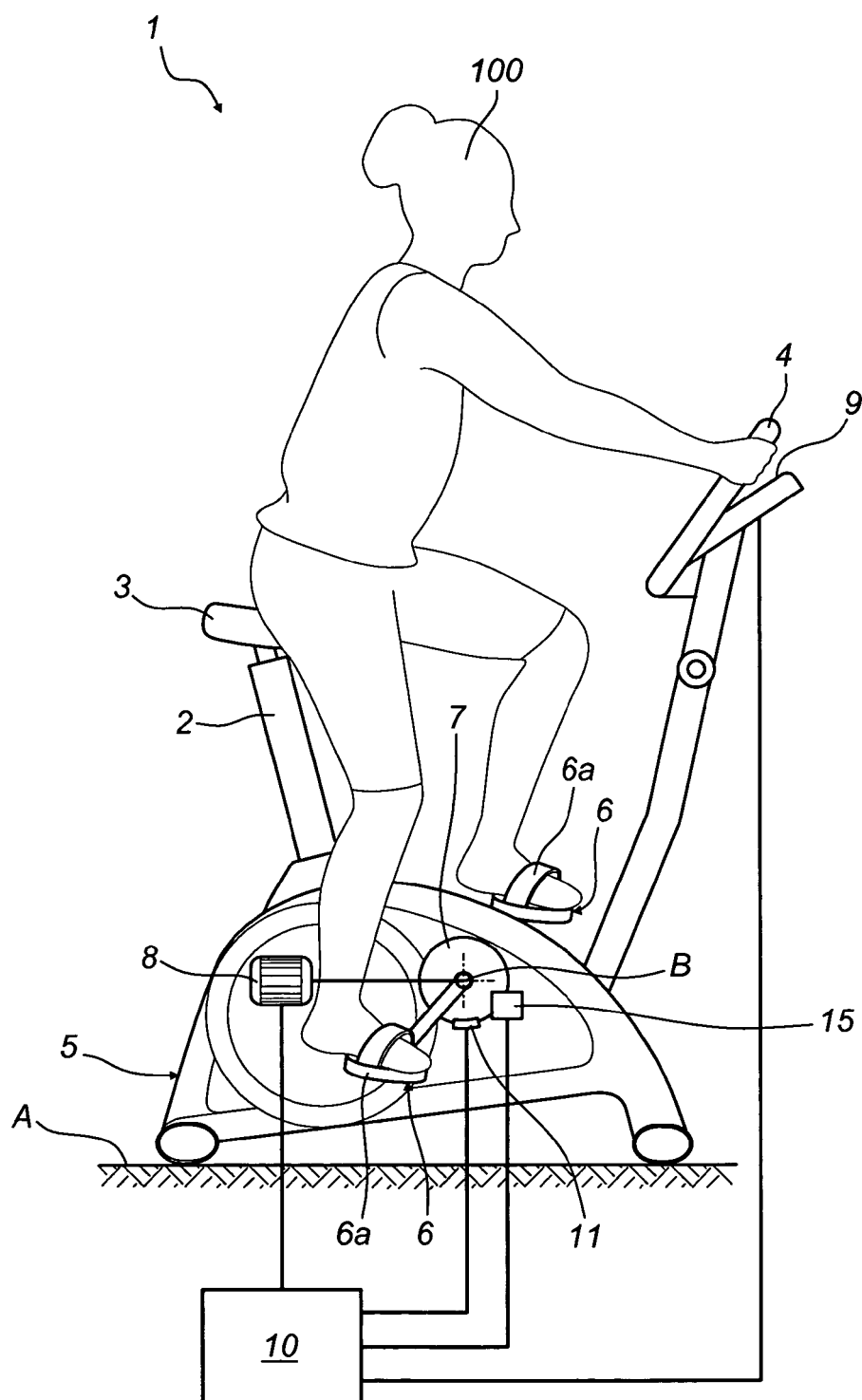
2. The exercise machine according to claim 1, wherein the interface (9) is configured to allow the user (100) to vary the maximum drive torque value ( $C_{\max}$ ) before or during the exercise.
3. The exercise machine according to any of the preceding claims, wherein the control unit (10) is configured to control the activation of the brake (11) even in the second exercising mode, when the drive torque generated by the electric motor (8) is zero, in response to an action applied by the user (100) to the support element (6) in the same direction as the preset rotation direction tending to increase the rotation speed of the support element (6) itself, in order to keep the rotation speed of the support element (6) close to the reference value ( $V_{\text{ref}}$ ).
4. The exercise machine according to any of the preceding claims, wherein the control unit (10):
  - comprises a timer configured to discretize an exercise time into a plurality of time intervals ( $\Delta T$ ) of preset duration;
  - is configured to automatically update the set speed reference value ( $V_{\text{ref}}$ ) at each time interval ( $\Delta T$ ), with the possibility of increasing or decreasing it according to the behaviour of the user (100) during that time interval ( $\Delta T$ ) or a preceding time interval.
5. The exercise machine according to claim 4, wherein the control unit (10) is set up to receive a signal representing a value of the rotation speed of the support element (6) and is programmed to compare the measured value with the reference value ( $V_{\text{ref}}$ ) at each time interval ( $\Delta T$ ), in order to increase the reference value ( $V_{\text{ref}}$ ) when the difference between the instantaneous value and the reference value ( $V_{\text{ref}}$ ) is greater than a preset quantity.
6. The exercise machine according to claim 4 or 5, wherein the control unit (10) is set up to receive a signal representing the value of the drive torque delivered by the electric motor (8) and is programmed to compare the measured value with a preset limit value ( $C_{\text{lim}}$ ) at each time interval ( $\Delta T$ ), and to reduce

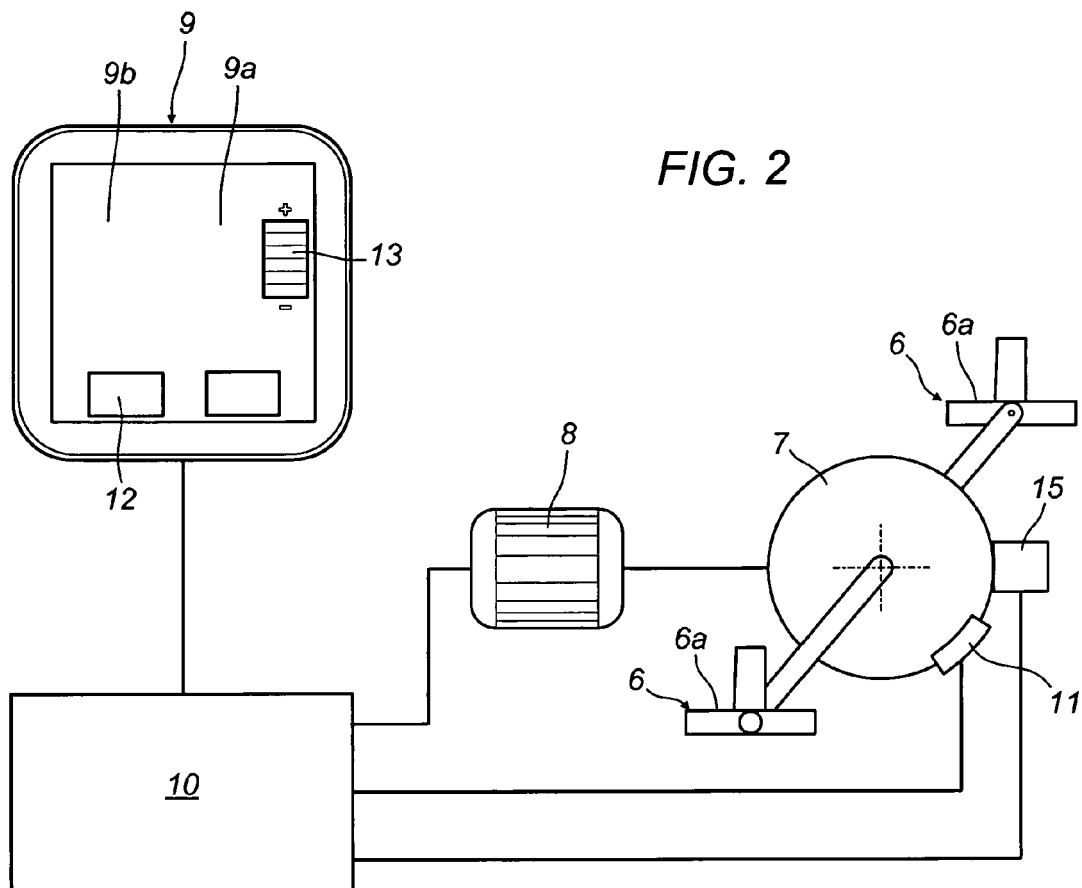
the reference speed when the torque measured is greater than the limit value ( $C_{\text{lim}}$ ).

7. The exercise machine according to any of the claims from 4 to 6, wherein each time interval ( $\Delta T$ ) is divided into a first sub-interval ( $\Delta T_1$ ), in which the control unit (10) is set up to receive a signal representing a value of the rotation speed of the support element (6) and is programmed to compare, at every time interval ( $\Delta T$ ), the measured value with the reference value ( $V_{\text{ref}}$ ) and to increase the reference value ( $V_{\text{ref}}$ ) when the difference between the instantaneous value and the reference value ( $V_{\text{ref}}$ ) is greater than a preset quantity, and a second sub-interval ( $\Delta T_2$ ), in which the control unit (10) is set up to receive a signal representing a value of the drive torque delivered by the electric motor (8) and is programmed to compare, at every time interval ( $\Delta T$ ), the measured value with a preset limit value ( $C_{\text{lim}}$ ) and to reduce the reference speed when the torque measured is greater than the limit value ( $C_{\text{lim}}$ ).
8. The exercise machine according to any of the claims from 6 to 10, wherein the control unit (10) and/or the interface (9) are configured to switch the exercise machine between an adaptive control mode, in which the control unit (10) is configured to vary the reference value ( $V_{\text{ref}}$ ) of the rotation speed of the support element as a function of a response from the user (100), and an isokinetic control mode, in which the control unit (10) is configured to control the drive torque of the electric motor (8) and/or the action of the brake during the exercise in order to keep the rotation speed of the support element (6) close to the reference value ( $V_{\text{ref}}$ ) set by the user (100).
9. A method for controlling an exercise machine having a frame (2), at least one hand or foot support element (6) for a user (100), rotatably connected to the frame (2), an electric motor (8) connected to the support element (6) to set the latter in rotation, and a brake (11) configured to be operatively applied to the support element, the method comprising the steps of:
  - offering to the user (100), through an interface (9), the possibility of setting a first exercising mode, where the user (100) moves the support element (6) by overcoming the action of the brake (11), and a second exercising mode where the motor (8) delivers a drive torque to move the support element at a predetermined speed and in a predetermined direction as a function of a set reference value ( $V_{\text{ref}}$ ) for the rotation speed of the support element (6), **characterized in that** it comprises, in the second exercising mode, the steps of:
    - receiving through a control unit (10) a set maximum value ( $C_{\max}$ ) for the drive torque;

- setting a maximum drive torque deliverable by the motor (8) during the exercise, on the basis of the maximum value set by the user (100);
  - activating the motor (8), through the control unit (10), with the drive torque necessary to move the support element (6) at a speed equal to the reference value ( $V_{ref}$ ), in the predetermined direction of rotation;
  - measuring the rotation speed of the support element (6);
  - driving the electric motor (8) in order to vary the delivered torque as a function of a comparison between the measured speed value and the reference value ( $V_{ref}$ ), so as to keep the rotation speed of the support element (6) close to the set reference value ( $V_{ref}$ ) irrespective of the direction of the action applied by the user (100), so that an action applied by the user (100) to the support element (6) in the same direction as the preset rotation direction corresponds to a decrease in the drive torque delivered by the electric motor (8), and an action applied by the user (100) to the support element (6) in the direction opposite to the preset rotation direction corresponds to an increase in the drive torque delivered by the electric motor (8), the increase in the drive torque being limited to reaching the set maximum value ( $C_{max}$ ).
10. The method according to claim 9, comprising a step of activating the brake (11) through the control unit (10) when the drive torque generated by the electric motor (8) is zero, in response to an action applied by the user (100) to the support element (6) in the same direction as the preset rotation direction tending to increase the rotation speed of the support element (6), in order to keep the rotation speed of the support element (6) close to the set reference value ( $V_{ref}$ ).
11. The method according to claim 9 or 10, comprising the following steps:
- discretizing an exercise time into a plurality of time intervals ( $\Delta T$ ) of preset duration;
  - updating at each time interval ( $\Delta T$ ), through the control unit (10), the speed reference value ( $V_{ref}$ ) set by the user (100), with the possibility of increasing or decreasing it according to the behaviour of the user (100) during that time interval ( $\Delta T$ ) or a preceding time interval.
12. The method according to claim 11, wherein the control unit (10), during the time interval ( $\Delta T$ ), performs the following steps:
- measuring a value of the rotation speed of the support element (6);
- comparing the measured value with the reference value ( $V_{ref}$ );
  - increasing the reference value ( $V_{ref}$ ) when the difference between the measured value and the reference value ( $V_{ref}$ ) is greater than a preset quantity.
13. The method according to claim 11 or 12, wherein the control unit (10), during the time interval ( $\Delta T$ ), performs the following steps:
- measuring the drive torque delivered by the electric motor (8);
  - comparing the measured value with a preset limit value ( $C_{lim}$ );
  - reducing the reference speed when the measured torque is greater than the limit value ( $C_{lim}$ ).

**FIG. 1**





**FIG. 4**

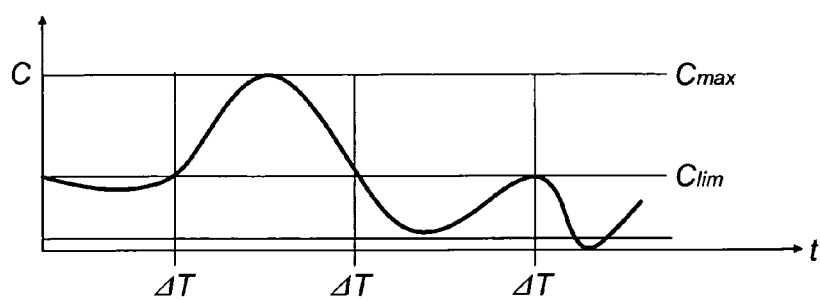
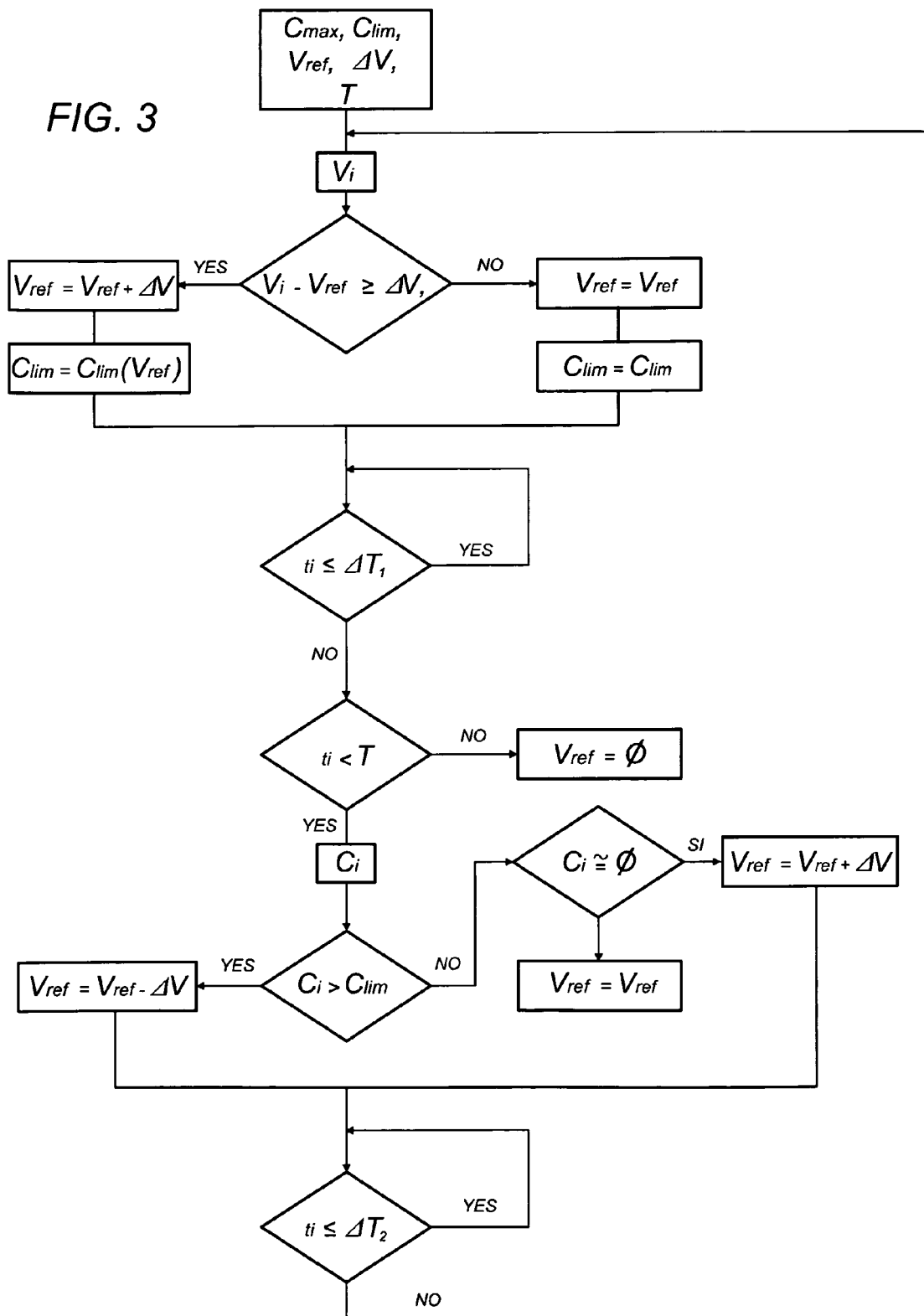


FIG. 3





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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                              |                                                      |                                             |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                              |                                                      |                                             |
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