(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 June 2021 (24.06.2021)

WIPO | PCT

(10) International Publication Number
WO 2021/124189 A1

(51) International Patent Classification:
B62M 11/04 (2006.01) *F16H 15/50* (2006.01)
F16H 15/04 (2006.01)

(21) International Application Number:
PCT/IB2020/062097

(22) International Filing Date:
17 December 2020 (17.12.2020)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
102019000024595 18 December 2019 (18.12.2019) IT

(72) Inventor; and
(71) Applicant: **ALIPERTI, Rosario** [IT/IT]; Via Alberto Braglia, 63, 41124 Modena (IT).

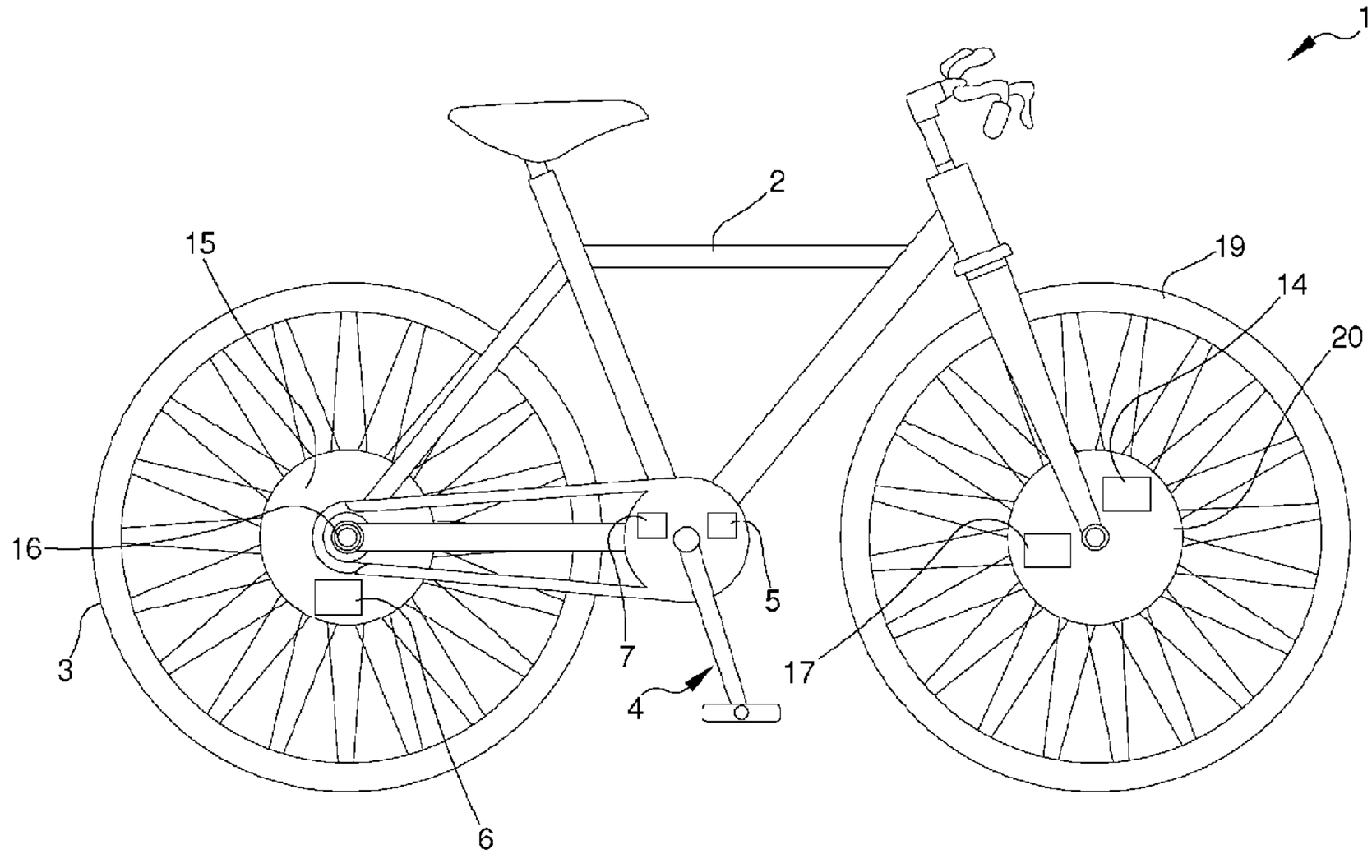
(74) Agent: **GRANA, Daniele**; c/o Brunacci & Partners S.r.l., Via Pietro Giardini, 625, 41125 Modena (MO) (IT).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,

(54) Title: EXCLUSIVELY HUMAN-POWERED BICYCLE WITH AUTOMATIC GEAR SHIFTING

Fig.1



(57) Abstract: The exclusively human-powered bicycle (1) with automatic gear shifting, comprises: a riding frame (2); a drive wheel (3) associated movable in rotation with the riding frame (2); one pedal set (4) associated movable in rotation with the riding frame (2); continuously variable motion transmission means (8) positioned between said pedal set (4) and said drive wheel (3), adapted to vary the transmission ratio between these seamlessly; control means (29) of the motion transmission means (8) provided with: sensing means (5, 6, 7, 10, 12) provided with: one torque sensing device (5) configured to detect the force applied by the user to said pedal set (4); a first speed sensing device (6) of the drive wheel (3); a second speed sensing device (7) of said pedal set (4); drive means (9, 11, 13, 30) configured to vary the transmission ratio depending on the force measured by the torque sensing device (5), on the speed measured by the first speed sensing device (6) and on the speed measured by the second speed sensing device (7).

[Continued on next page]

WO 2021/124189 A1

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

EXCLUSIVELY HUMAN-POWERED BICYCLE WITH AUTOMATIC GEAR SHIFTING

Technical Field

The present invention relates to an exclusively human-powered bicycle with automatic gear shifting.

Background Art

Several types of bicycles with automatic gear shifting are known and usually used by their users for urban and extra-urban transport and/or for recreational sports activities.

Generally, this type of bicycle is provided with a CVT (Continuous Variable Transmission), which has the purpose of varying the transmission ratio between the crank and the drive wheel of the bicycle itself without interruption.

In fact, CVTs employed by bicycles of known type are generally without the known cassette comprising a plurality of toothed wheels of different diameters and selectively meshed by the drive belt (or chain) depending on the desired transmission ratio.

In addition, the bicycles with automatic gear shifting of known type are provided with a CVT control unit and with two speed sensing devices, configured to detect the spinning speed of the crank and of the drive wheel, respectively, and operationally connected to the control unit.

This way, the control unit varies the transmission ratio between the crank and the drive wheel according to the speeds detected by the speed sensing devices.

In particular, a bicycle with automatic gear shifting is known from U.S. Patent US2018202527A1, in which a version of CVT integrated into the rear wheel hub of the bicycle is proposed.

The bicycles with automatic gear shifting of known type are however susceptible to improvements related to the variation of the transmission ratio between the crank and the drive wheel.

In fact, this type of bicycle varies the transmission ratio between the crank and the drive wheel solely depending on the speeds detected by the speed sensing devices.

This approach significantly limits the ability of the bicycles with automatic gear shifting of known type to vary the transmission ratio between the crank and the

drive wheel depending on the real needs of the user, e.g. depending on the type of use of the bicycle itself, depending on the physical form of the users themselves and the like.

In other words, the bicycles with automatic gear shifting of known type vary the transmission ratio between the crank and the drive wheel in an extremely rough and imprecise manner.

An additional drawback of the bicycles with automatic gear shifting of known type relates to the energy consumption of the CVT.

In fact, CVTs used by bicycles with automatic gear shifting of known type require a considerable consumption of electrical energy and therefore must be operationally connected to a special power supply battery of particularly bulky dimensions that must be mounted on board the bicycle itself.

This drawback limits the bicycles with automatic gear shifting to the category of bicycles of the electric type, in which the battery is also used to assist the user of the bicycle in the propulsion of the same.

In fact, the weight and overall dimensions of these batteries make inconvenient to use the CVT on exclusively human-powered bicycles, which would be particularly heavy and uncomfortable to use.

These drawbacks reduce the ease of use of the bicycles with automatic gear shifting of known type, making them less appealing to the consumer.

Description of the Invention

The main aim of the present invention is to devise a bicycle with an automatic gear shifting that allows the transmission ratio between the crank and the drive wheel to be automatically varied so as to maximize the riding comfort of the bicycle itself during each phase of pedaling compared to the bicycles with automatic gear shifting of known type.

A further object of the present invention is to devise a bicycle with an automatic gear shifting that allows the transmission ratio between the crank and the drive wheel to be continuously varied according to the needs of one or more users of the bicycle and to the condition of use of the bicycle itself.

An additional object of the present invention is to devise an exclusively human-powered bicycle with automatic gear shifting.

Another object of the present invention is to devise a bicycle with automatic gear shifting which allows overcoming the above mentioned drawbacks of the prior within a simple, rational, easy, effective to use and low cost solution.

The objects set out above are achieved by the present bicycle with automatic gear shifting having the characteristics of claim 1.

Brief Description of the Drawings

Other characteristics and advantages of the present invention will become more evident from the description of a preferred, but not exclusive, embodiment of a bicycle with automatic gear shifting, illustrated by way of an indicative, yet non-limiting embodiment, in the accompanying tables of drawings wherein:

Figure 1 is a schematic view of the bicycle according to the invention;

Figures 2 and 3 are graphs describing the ratio between the spinning speed of the drive wheel and the force applied to the pedal set according to the invention;

Figure 4 is a block diagram of some bicycle components according to the invention.

Embodiments of the Invention

With particular reference to these figures, reference numeral 1 globally indicates an exclusively human-powered bicycle with automatic gear shifting.

The exclusively human-powered bicycle 1 with automatic gear shifting comprises:

- a riding frame 2 used by at least one user to ride the bicycle 1;
- at least one drive wheel 3 associated movable in rotation with the riding frame 2;
- at least one pedal set 4 associated movable in rotation with the riding frame 2;
- continuously variable motion transmission means 8 positioned between the pedal set 4 and the drive wheel 3, kinematically connected to the latter ones and adapted to vary the transmission ratio between these seamlessly.

In the remainder of the present discussion, the term “pedal set” is meant to indicate a pedal set 4 of known type, i.e., provided with a pedal, a crank mechanically coupled to the pedal, and a central gear crown associated with the crank and coupled movable in rotation to the riding frame 2 so as to make a central movement like that employed by the bicycles of known type.

This way, the user of the bicycle 1 gives a spinning motion to the pedal set 4 to

spin the drive wheel 3.

Moreover, according to the invention, the motion transmission means 8 comprise a CVT (Continuously Variable Transmission) mechanical gear shifting adapted to impose between the pedal set 4 and the drive wheel 3 a transmission ratio of any value within a minimum and a maximum value of transmission ratios.

In particular, the bicycle 1 comprises control means 29 of the motion transmission means 8 provided with:

- sensing means 5, 6, 7, 10, 12 comprising:
  - at least one torque sensing device 5 configured to detect the force applied by the user to the pedal set 4 while riding the bicycle 1;
  - at least a first speed sensing device 6 of the drive wheel 3 configured to detect the spinning speed of the latter;
  - at least a second speed sensing device 7 of the pedal set 4 configured to detect the spinning speed of the latter;
- drive means 9, 11, 13, 30 operationally connected to the sensing means and configured to vary the transmission ratio between the pedal set 4 and the drive wheel 3 depending on the force measured by the torque sensing device 5, on the speed measured by the first speed sensing device 6 and on the speed measured by the second speed sensing device 7.

In particular, the drive means 9, 11, 13, 30 are configured to operate on the CVT gear shifting of the motion transmission means 8 so as to impose between the pedal set 4 and the drive wheel 3 a transmission ratio of any value within a continuous range of values.

Advantageously, the drive means 9, 11, 13, 30 comprise at least one processing unit 9 configured to determine at least one value of an optimal transmission ratio $Z_{d_{opt}}$ to be applied between the pedal set 4 and the drive wheel, in such a way as to keep, between the speed value and the force value of the pedal set 4, a mathematical ratio of the type $\sum_{k=0}^{n} a_k \, \omega_p^k - F_p = 0$, wherein the terms ω_p and F_p correspond to the spinning speed and to the force applied to the pedal set 4 respectively, and the term a_k corresponds to a plurality of predefined parameters.

The expression “optimal transmission ratio”, which will be referred to as the optimal ratio in the following section, is meant to indicate the ratio that, depending

on the measurements made by the torque sensing device 5 and by the first and second speed sensing devices 6 and 7, minimizes the effort and sense of fatigue felt by the cyclist according to the aforementioned mathematical ratio.

In fact, depending on the power applied on the pedal set 4 by the user, it is possible to define a plane of points ω_p-F_p, shown in Figure 2, on which a plurality of constant power curves can be identified, that is curves describing the set of pairs of points ω_p-F_p which correspond to a constant power value, such as e.g. the curves P_0, P_1, P_2.

In particular, on each of these curves it is possible to identify an optimal working point (L_0, L_1, L_2), i.e. the point at which, the power supplied by the user being equal, the effort and the sense of fatigue felt by the user are minimized.

Therefore, the mathematical formula $\sum_{k=0}^{n} a_k\, \omega_p^k - F_p = 0$ approximates the set of optimal working points of each constant power curve in the plane ω_p-F_p.

In more detail, the processing unit 9 is configured to determine the optimal transmission ratio $Z_{d_{opt}}$ starting from a mathematical ratio of the type $\left(F_p - a_0\right)Z_{d_{opt}}^{n} - \sum_{k=1}^{n} a_k\, Z_{d_{opt}}^{(n-k)} Z'^{k} \omega_{opt}^{k} = 0$, wherein $Z' = \omega_r/\omega_{opt}$ and where the term ω_r corresponds to the spinning speed of the drive wheel 3, and the term ω_{opt} corresponds to a predefined parameter.

In particular, the mathematical ratio

$\left(F_p - a_0\right)Z_{d_{opt}}^{n} - \sum_{k=1}^{n} a_k\, Z_{d_{opt}}^{(n-k)} Z'^{k} \omega_{opt}^{k} = 0$ is obtained by replacing

$\omega_p = Z'\omega_{opt}/Z_{d_{opt}}$ in the mathematical ratio $\sum_{k=0}^{n} a_k\, \omega_p^k - F_p = 0$.

In detail, from the above mentioned mathematical ratio we obtain that

$Z_{d_{opt}} = Z' \cdot R\left(\left(F_p - a_0\right)Z_{d_{opt}}^{n} - \sum_{k=1}^{n} a_k\, Z_{d_{opt}}^{(n-k)} \omega_{opt}^{k}\right)$, in which $R\left(\left(F_p - a_0\right)Z_{d_{opt}}^{n} - \sum_{k=1}^{n} a_k\, Z_{d_{opt}}^{(n-k)} \omega_{opt}^{k}\right)$ is a real root of the polynomial of order n.

This way, by imposing $Z_{d_{opt}}$ as the transmission ratio between the pedal set 4 and the drive wheel 3, we obtain that the spinning speed ω_p and the force F_p applied to the pedal set 4 are related to each other by the ideal curve $\sum_{k=0}^{n} a_k\, \omega_p^k - F_p = 0$.

Conveniently, the drive means 9, 11, 13, 30 comprise at least one storage device 30 configured to store at least one of either:

- a plurality of predetermined parameters of the parameter ω_{opt}; or
- a plurality of predetermined parameters a_{k_0} adapted to vary the value of the parameters a_k.

In particular, each of the predetermined parameters is selectable by the user to modify in a different way with respect to the others the optimal transmission ratio $Z_{d_{opt}}$, depending on the physical/athletic form of the users themselves.

In fact, a particularly trained user of the bicycle 1 is able to sustain a higher average spinning speed of the pedal set 4 than a poorly trained user of the bicycle 1.

Therefore, the ideal curve described by the ratio $\sum_{k=0}^{n} a_k \, \omega_p^k - F_p = 0$ which allows determining the optimal ratio for a trained user will be shifted downwards with respect to that of a less trained user who, power being equal, will prefer a lower spinning speed of the pedal set 4, as shown in Figure 3.

Advantageously, the sensing means 5, 6, 7, 10, 12 comprise at least one sensing device 10 selected from the list comprising a temperature sensor, pressure sensor, acceleration sensor, gyroscope and magnetometer.

This way, the drive means 9, 11, 13, 30 are configured to vary the value of optimal transmission ratio $Z_{d_{opt}}$ between the pedal set 4 and the drive wheel 3 depending on the measured physical quantity.

In particular, the drive means 9, 11, 13, 30 are configured to continuously vary the value of optimal transmission ratio $Z_{d_{opt}}$ depending on the measured physical quantity.

Preferably, the sensing means 5, 6, 7, 10, 12 comprise a plurality of sensing devices 10.

In particular, according to a possible embodiment of the bicycle 1, the sensing means 5, 6, 7, 10, 12 comprise at least one sensing device 10 for each type of sensing device mentioned in the preceding list.

This way, the value of the optimal ratio is varied depending on the physical quantity measured by each of the sensing devices 10.

Specifically, according to the invention, the value of the optimal ratio is varied depending on the predetermined parameters and depending on the measured physical quantity. This variation is expressed by the following formula:

$$a_k = a_{k_0} + f(x)$$

Where a_k is the generic parameter of the ideal curve, a_{k_0} is the predetermined parameter selected by the user and where $f(x)$ is a variable value calculated in continuity depending on the measured physical quantity defined as x.

In a possible embodiment of the bicycle 1, the variation of the optimal ratio is expressed by the following mathematical ratio:

$$a_k = a_{k_0} + G_{p_T}(T - T_0) + G_{p_P}(P - P_0)$$

Where $f(x) = G_{p_T}(T - T_0) + G_{p_P}(P - P_0)$, a_{k_0} is evaluated at room temperature, e.g. for values of T_0 between 17-23 °C, and at ambient pressure, e.g. for values of P_0 in the range of average atmospheric pressure of 101.3kPa and where G_{p_T} and G_{p_P} are the thermal and barometric gradient coefficients of the generic parameter, respectively.

Similarly, other physical quantities measured by the sensing devices 10 used can be taken into account, by entering the respective parameters and average values into the above formula.

Advantageously, the control means 29 comprise interface means, not shown in the figures, configured to indicate the value of at least one of either ω_{opt} or a_{k_0}.

Preferably, the interface means are of the type of an electronic manual input device by the user, such as e.g. a touch screen, a selector switch or the like.

In addition, the interface means are preferably mounted on the riding frame 2.

Conveniently, the control means 29 comprise communication means 31 configured to communicate with at least one remote drive device 32 not shown in the figures.

Advantageously, the communication means 31 are configured to send to the remote drive device 32 one or more riding data of the bicycle 1, such as e.g. the data measured by the sensing means 5, 6, 7, 10, 12.

Preferably, the communication means 31 are of the type of an electronic communication device for data transmission, e.g. via Bluetooth, mobile network, Wi-Fi and the like.

In addition, the remote drive device 32 is preferably an electronic device of the type of a smart-phone, tablet, PC, or the like.

Furthermore, alternative embodiments of the bicycle 1 cannot be ruled out wherein

the interface means coincide with the remote drive device 32.

In particular, the drive means 9, 11, 13, 30 comprise at least one actuator assembly 11 kinematically connected to the motion transmission means 8 to vary the transmission ratio between the pedal set 4 and the drive wheel 3.

This way, the drive means 9, 11, 13, 30 continuously vary the transmission ratio between the pedal set 4 and the drive wheel 3 by means of the actuator assembly 11.

In particular, the actuator assembly 11 operates on the motion transmission means 8 so as to set the optimal transmission ratio $Z_{d_{opt}}$ determined by the processing unit 9 between the pedal set 4 and the drive wheel 3.

Advantageously, the actuator assembly 11 is provided with reduction means, not shown in the figures, coupled to the motion transmission means 8.

However, in the case where the bicycle 1 is moving, but the pedal set 4 is stationary, i.e., when the pedal set 4 is mechanically uncoupled from the drive wheel 3, it may be understood that it is not possible to determine the optimum ratio as previously described.

Accordingly, the drive means 9, 11, 13, 30 are configured to vary the transmission ratio according to alternative calculation methods.

In this regard, the sensing means 5, 6, 7, 10, 12 comprise at least one position sensing device 12 of the actuator assembly 11 configured to detect the position of the actuator assembly itself.

Preferably, the position sensing device 12 is an encoder.

Furthermore, the drive means 9, 11, 13, 30 comprise at least one storage unit 13 configured to store a plurality of preset spinning speed values of the drive wheel 3 and a plurality of preset position values of the actuator assembly 11, each of which is logically related to a corresponding preset spinning speed value, each preset position of the actuator assembly 11 corresponding to a preset transmission ratio value.

In other words, a correspondence is established between each predetermined position of the actuator assembly 11 and the transmission ratio imposed between the pedal set 4 and the drive wheel 3. In fact, it is the same actuator assembly 11 that varies the transmission ratio.

Therefore, it is convenient to store inside the storage unit 13 the preset spinning speed values logically correlated to the predefined positions. This way, such speed values are logically correlated to the preset transmission ratio values.

Preferably, this logical correlation between the preset spinning speed values and the predefined position values is defined by a calibration of the motion transmission means 8, in this case the CVT gear shifting.

Furthermore, the drive means 9, 11, 13, 30 are configured to move the actuator assembly 11 to the predefined position corresponding to the preset spinning speed value of the drive wheel 3 when the latter coincides with the measured spinning speed value of the drive wheel 3.

Thus, the drive means 9, 11, 13, 30 are configured to vary the transmission ratio differently if the bicycle 1 is moving, but the pedal set 4 is stationary.

In particular, the drive wheel 3 comprises at least one drive hub 15 associated movable in rotation with the riding frame 2.

In addition, the bicycle 1 comprises at least one sprocket 16 kinematically coupled in rotation and with overrunning clutch, or also referred to as a free wheel, to the drive hub 15.

In other words, the motion transmission means 8 are positioned between a drive hub 15 of known type and a sprocket 16 of known type, which are mechanically coupled to each other by means of a free wheel mechanism of known type, i.e., by means of a uncoupling mechanism of the drive hub 15 and of the sprocket 16 when the latter rotates with a lower speed than the drive hub 15.

This way, when the sprocket 16 is engaged, it transmits the motion at input to the motion transmission means 8 which transmit the motion at output to the drive hub 15 and consequently to the drive wheel 3.

Advantageously, the motion transmission means 8 are positioned between the drive hub 15 and the sprocket 16.

Furthermore, the bicycle 1 comprises at least one transmission element, such as e.g. a chain, a belt or the like, not shown in the figures, positioned between the sprocket 16 and the pedal set 4, and mechanically coupled to the latter to allow the transmission of motion between these, substantially as occurs with reference to the bicycles of known type.

However, unlike the bicycles of known type, the drive means 9, 11, 13, 30 continuously and seamlessly vary the transmission ratio between the sprocket 16 and the drive hub 15 during the use of the bicycle 1 by the user.

Moreover, the control means 29 are configured to check when the sprocket 16 is coupled to the drive hub 15, that is, when:

- both spinning speeds of the pedal set 4 and of the drive wheel 3 are faster than a corresponding predefined threshold speed; and
- at least one of either the acceleration of the pedal set 4 or the acceleration of the drive wheel 3 is faster than a corresponding predefined threshold acceleration.

Preferably, the processing unit 9 is configured to calculate the acceleration of at least one of either the pedal set 4 or the drive wheel 3 starting from the variation in speed measured by the first speed sensing device 6 and by the second speed sensing device 7, respectively.

Advantageously, the drive means 9, 11, 13, 30 are configured to apply between the pedal set 4 and the drive wheel 3 the value of the optimal transmission ratio $Z_{d_{opt}}$ when the sprocket 16 is coupled to the drive hub 15, and the value of the preset transmission ratio when the sprocket 16 is uncoupled from the drive hub 15.

Therefore, when the sprocket 16 is uncoupled from the drive hub 15, the drive means 9, 11, 13, 30 vary the transmission ratio depending on the spinning speed of the drive wheel 3.

This way, when the user of the bicycle 1 resumes pedaling following a stop of the pedal set 4 and the sprocket 16 is coupled to the drive hub 15, the transmission ratio applied between the pedal set 4 and the drive wheel 3 is not the same as that applied at the instant prior to the stop of the pedal set 4.

This device allows the user to resume pedaling with a transmission ratio that is appropriate for the speed of the bicycle 1.

For example, the users who resume pedaling at the end of a descent, during which they have acquired a certain speed, will have to be able to maintain the same speed acquired during the descent itself. Therefore, according to the invention, the transmission ratio between the pedal set 4 and the drive wheel 3 at the end of the descent will be increased by a certain factor compared to the transmission ratio at

the beginning of the descent.

However, as a result of the coupling between the sprocket 16 and the drive hub 15, the drive means 9, 11, 13, 30 are configured to vary again the transmission ratio between the pedal set 4 and the drive wheel 3 depending on the optimum ratio.

Conveniently, the bicycle 1 comprises power supply means 28 of the control means 29, mounted on the riding frame 2 and provided with:

- at least one of at least one generator device 17 and at least one electrical charge storage device 18;
- at least one power supply circuit 26 operationally connected to the control means 29 and operationally connected to at least one of either the generator device 17 or the electrical charge storage device 18.

Preferably, the power supply means 28 comprise both the generator device 17 and the electrical charge storage device 18.

In particular, the generator device 17 is of the type selected from the list comprising a dynamo and an alternator.

Preferably, the generator device 17 is an alternator.

Advantageously, the bicycle 1 comprises at least one free wheel 19 provided with at least one free hub 20 associated movable in rotation with the riding frame 2.

In addition, the generator device 17 is interposed between the free hub 20 and the riding frame 2.

Preferably, the generator device 17 is integrated at least partly into the free hub 20.

Preferably, inside the free hub 20 is arranged a plurality of permanent magnetic elements and a stator winding wound to a plurality of polar slots formed around a rotating pin associated with the riding frame 2 and around which the free hub 20 is coupled movable in rotation.

This way, during the rotation of the free wheel 19, the generator device 17 generates a voltage and a current having a frequency and intensity proportional to the spinning speed of the free wheel 19.

Preferably, the voltage and current generated by the generator device 17 are of the sinusoidal kind.

Conveniently, the sensing means 5, 6, 7, 10, 12 comprise at least a third speed sensing device 14 configured to detect the spinning speed of the free wheel 19.

Preferably, according to the invention, the third speed sensing device 14 preferably coincides with the generator device 17.

In fact, the generator device 17 can be used both as an alternator and as a spinning speed sensor of the free wheel 19.

Advantageously, the power supply circuit 26 comprises at least one power factor correction circuit 21 operationally connected downstream of the generator device 17 and configured to reduce the reactive charging power coming from the generator device 17.

In particular, the power factor correction circuit 21 is provided with at least one equivalent capacitive element configured to take a plurality of equivalent capacitance values.

In addition, the drive means 9, 11, 13, 30 are configured to vary the equivalent capacitance value depending on the speed value measured by the third speed sensing device 14.

Preferably, the power supply circuit 26 comprises at least one rectifier circuit 33 operationally connected downstream of the power factor correction circuit 21.

This way, the output voltage from the power factor correction circuit 21 is appropriately rectified.

Furthermore, the power supply circuit 26 comprises at least one DC-DC converter circuit 34 operationally connected downstream of the rectifier circuit 33.

This way, the output voltage from the rectifier circuit 33 is maintained at a constant voltage value used to power the control means 29.

Advantageously, the power supply circuit 26 comprises at least one power supply input 23 operationally connectable to external power supply means and configured to charge the electrical charge storage device 18.

By the expression “external power supply means” is meant any external source of electrical power, such as e.g. of the type of a battery pack, an outlet to a power grid, and the like.

Furthermore, the power supply circuit 26 comprises at least one charging circuit 22 operationally connected to the generator device 17 and to the electrical charge storage device 18, and configured to charge the latter with the power supply provided by the generator device 17.

This way, the charging circuit 22 allows the electrical charge storage device 18 to be charged by means of the power supply provided by the generator device 17 when the latter generates electrical energy, i.e., when the bicycle 1 is in motion.

Also advantageously, the charging circuit 22 is operationally connected to the power supply input 23 as well.

In particular, the charging circuit 22 is configured to charge the electrical charge storage device 18 selectively with one of either the power supply provided by the generator device 17 or the power supply provided by the power supply input 23.

This way, in the event of the electrical charge storage device 18 being completely discharged, e.g. as a result of prolonged non-use of the bicycle 1, the charging circuit 22 is configured to charge the electrical charge storage device 18 via the power supply input 23.

Preferably, the electrical charge storage device 18 is of the type of a buffer battery periodically charged by the generator device 17 during the movement of the bicycle 1.

Furthermore, the electrical charge storage device 18 is preferably of the type of a battery integrated in the drive means 9, 11, 13, 30, to which it provides power only when the bicycle 1 is stationary.

The power supply input 23, on the other hand, is preferably of the type of an electrical connector connectable to the external power supply means of the type known to the engineer in the art, such as, e.g., the national power grid or even such as battery packs or the like.

Conveniently, the power supply circuit 26 comprises at least one regulation circuit 24 operationally connected to the charging circuit 22 and configured to regulate the value of the charging current of the electrical charge storage device 18 depending on at least one of either the charge level of the latter or the speed value of the free wheel 19.

Preferably, the regulation circuit 24 is configured to regulate the value of the charging current of the electrical charge storage device 18 depending on the charge level of the latter and the speed value of the free wheel 19.

In fact, the current generated by the generator device 17 depends on the spinning speed of the free wheel 19.

This way, the regulation circuit 24 is configured to optimize the use of the generator device 17.

Conveniently, the power supply circuit 26 comprises at least one load sharing circuit 25 operationally connected to the generator device 17 and to the electrical charge storage device 18 and configured to power the control means 29 selectively with one of either the power supply provided by the generator device 17 or the power supply provided by the electrical charge storage device 18.

In particular, the load sharing circuit 25 is configured to power the control means 29, 13 with the power supply provided by the electrical charge storage device 18 when the generator device 17 is not generating electricity, i.e., when the bicycle 1 is substantially stationary.

On the contrary, the load sharing circuit 25 is configured to power the control means 29 with the power supply provided by the generator device 17 when the latter is producing electricity, i.e., when the bicycle 1 is in motion.

In more detail, the load sharing circuit 25 is preferably operationally connected upstream of the DC-DC converter circuit.

Advantageously, the bicycle 1 comprises at least one bypass circuit 27 operationally connected to the electrical charge storage device 18 and to the processing unit 9 and configured to power supply the latter ones directly with the power supply provided by the electrical charge storage device 18.

Conveniently, the processing unit 9 is adapted to configure the power supply means 28 between at least one active condition, wherein the bypass circuit 27 is deactivated and the load sharing circuit 25 is activated and supplies the control means 29, and at least one home configuration, wherein the load sharing circuit 25 is deactivated and the bypass circuit 27 is activated and supplies the processing unit 9.

This way, the processing unit 9 is always powered independently of the other components of the control means 29.

In fact, the processing unit 9 is configured to deactivate the power supply of any other component of the bicycle 1.

In particular, the processing unit 9 is configured to deactivate the power supply of any other component of the bicycle 1 when the same is stationary for longer than a

specified amount of time.

This solution allows preserving the electrical charge of the electrical charge storage device 18 when the bicycle 1 is stationary.

Furthermore, the processing unit 9 is configured to activate the power supply of any other component of the bicycle 1 as a result of the generation of at least one of either a current or a voltage by the generator device 17.

In other words, the processing unit 9 only activates the power supply to any other component of the bicycle 1 when the bicycle is set in motion.

It has in practice been ascertained that the described invention achieves the intended objects.

In particular, the fact is underlined that the control means allow significantly increasing the riding comfort of the bicycle compared to the bicycles of known type.

In particular, the control means make it possible to impose between the pedal set and the drive wheel an optimal transmission ratio, which is determined and varied depending on the spinning speed of the drive wheel and depending on the force applied to the central unit.

In addition, the generator device allows making an exclusively human-powered bicycle with automatic gear shifting.

In fact, the generator device allows powering the control means without the need to use heavy and bulky batteries on board the bicycle, which must necessarily be used at least partly to assist the user in the propulsion of the bicycle itself, which would otherwise be particularly heavy and uncomfortable to use.

CLAIMS

1) Exclusively human-powered bicycle (1) with automatic gear shifting, comprising:

- a riding frame (2) used by at least one user to ride said bicycle (1);
- at least one drive wheel (3) associated movable in rotation with said riding frame (2);
- at least one pedal set (4) associated movable in rotation with said riding frame (2);
- continuously variable motion transmission means (8) positioned between said pedal set (4) and said drive wheel (3), kinematically connected to the latter ones and adapted to vary the transmission ratio between these seamlessly, said user giving a spinning motion to said pedal set (4) to spin said drive wheel (3);

characterized by the fact that it comprises control means (29) of said motion transmission means (8) provided with:

- sensing means (5, 6, 7, 10, 12) provided with:
  - at least one torque sensing device (5) configured to detect the force applied by the user to said pedal set (4) while riding said bicycle (1);
  - at least a first speed sensing device (6) of said drive wheel (3) configured to detect the spinning speed of the latter;
  - at least a second speed sensing device (7) of said pedal set (4) configured to detect the spinning speed of the latter;
- drive means (9, 11, 13, 30) operationally connected to said sensing means (5, 6, 7, 10, 12) and configured to vary the transmission ratio between said pedal set (4) and said drive wheel (3) depending on the force measured by said torque sensing device (5), on the speed measured by said first speed sensing device (6) and on the speed measured by said second speed sensing device (7).

2) Bicycle (1) according to claim 1, characterized by the fact that said drive means (9, 11, 13, 30) comprise at least one processing unit (9) configured to determine at least one value of an optimal transmission ratio Z_{d_opt} to be applied

between said pedal set (4) and said drive wheel (3) in such a way as to keep, between the speed value and the force value applied to said pedal set (4), a mathematical ratio of the type $\sum_{k=0}^{n} a_k \omega_p^k - F_p = 0$, wherein the terms ω_p and F_p correspond to the spinning speed and to the force applied to said pedal set (4) respectively, and the term a_k corresponds to a plurality of predefined parameters.

3) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said processing unit (9) is configured to determine said optimal transmission ratio Z_{d_opt} starting from a mathematical ratio of the type $(F_p - a_0)Z_{d\_opt}^n - \sum_{k=1}^{n} a_k Z_{d\_opt}^{(n-k)} Z'^k \omega_{opt}^k = 0$, wherein $Z' = \omega_r/\omega_{opt}$ and where the term ω_r corresponds to the spinning speed of said drive wheel (3), and the term ω_{opt} corresponds to a predefined parameter.

4) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said drive means (9, 11, 13, 30) comprise at least one storage device (30) configured to store at least one of either:

- a plurality of predetermined parameters of said parameter ω_{opt}; or
- a plurality of predetermined parameters a_{k_0} adapted to vary the value of said parameters a_k;

each of said predetermined parameters is selectable by said user to modify in a different way from the others said optimal transmission ratio Z_{d_opt} depending on the physical/athletic form of the user.

5) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said sensing means (5, 6, 7, 10, 12) comprise at least one sensing device (10) selected from the list comprising a temperature sensor, pressure sensor, acceleration sensor, gyroscope and magnetometer and by the fact that said drive means (9, 11, 13, 30) are configured to vary the optimal transmission ratio Z_{d_opt} between said pedal set (4) and said drive wheel (3) depending on said measured physical quantity.

6) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said drive means (9, 11, 13, 30) comprise at least one actuator

assembly (11) coupled to said motion transmission means (8) to vary said transmission ratio between said pedal set (4) and said drive wheel (3).

7) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said sensing means (5, 6, 7, 10, 12) comprise at least one position sensing device (12) of said actuator assembly (11) configured to detect the position of the same actuator assembly.

8) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said drive means (9, 11, 13, 30) comprise at least one storage unit (13) configured to store a plurality of preset spinning speed values of said drive wheel (3) and a plurality of preset position values of said actuator assembly (11), each of which is logically related to a corresponding preset spinning speed value, each preset position of said actuator assembly (11) corresponding to a preset transmission ratio value and said drive means (9, 11, 13, 30) being configured to move said actuator assembly (11) to the preset position corresponding to the preset spinning speed value of said drive wheel (3) when the latter coincides with the measured spinning speed value of said drive wheel (3).

9) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that:

- said drive wheel (3) comprises at least one drive hub (15) by means of which said drive wheel (3) is associated movable in rotation with said riding frame (2);
- it comprises at least one sprocket (16) kinematically coupled in rotation and with overrunning clutch to said drive hub (15);
- said motion transmission means (8) are positioned between said drive hub (15) and said sprocket (16);
- said control means (29) are configured to check when said sprocket (16) is coupled to said drive hub (15), i.e. when:
  - both spinning speeds of said pedal set (4) and said drive wheel (3) are faster than a corresponding predefined threshold speed; and
  - at least one of either the acceleration of said pedal set (4) or the

acceleration of said drive wheel (3) is faster than a corresponding predefined threshold acceleration.

10) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said drive means (9, 11, 13, 30) are configured to apply between said pedal set (4) and said drive wheel (3) the value of said optimal transmission ratio Z_{d_opt} when said sprocket (16) is coupled to said drive hub (15), and the value of said preset transmission ratio when said sprocket (16) is uncoupled from said drive hub (15).

11) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that it comprises power supply means (28) of said control means (29), mounted on said riding frame (2) and provided with:

- at least one of at least one generator device (17) and at least one electrical charge storage device (18);
- at least one power supply circuit (26) operationally connected to said control means (29) and operationally connected to at least one of either said generator device (17) or said electrical charge storage device (18).

12) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said power supply circuit (26) comprises at least one load sharing circuit (25) operationally connected to said generator device (17) and to said electrical charge storage device (18), and configured to power said control means (29) selectively with one of either the power supply supplied by said generator device (17) or the power supply supplied by said electrical charge storage device (18).

13) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said power supply circuit (26) comprises at least one charging circuit (22) operationally connected to said generator device (17) and to said electrical charge storage device (18) and configured to charge the latter with the power supply supplied by said generator device (17).

14) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that it comprises at least one free wheel (19) provided with at least one free hub (20) by interposition of which said free wheel (19) is associated

movable in rotation with said riding frame (2) and by the fact that said generator device (17) is interposed between said free hub (20) and said riding frame (2).

15) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said drive means (9, 11, 13, 30) comprise at least a third speed sensing device (14) configured to detect the spinning speed of said free wheel (19).

16) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said third speed sensing device (14) coincides with said generator device (17).

17) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said power supply circuit (26) comprises at least one regulation circuit (24) operationally connected to said charging circuit (22) and configured to regulate the value of the charging current of said electrical charge storage device (18) depending on at least one of either the charge level of the latter or the speed value of said free wheel (19).

18) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said power supply circuit (26) comprises at least one power factor correction circuit (21) operationally connected downstream of said generator device (17) and configured to reduce the reactive charging power coming from said generator device (17).

19) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said power supply means (28) comprise at least one bypass circuit (27) operationally connected to said electrical charge storage device (18) and to said processing unit (9) and configured to supply directly the latter ones using the power supply supplied by said electrical charge storage device (18).

20) Bicycle (1) according to one or more of the preceding claims, characterized by the fact that said processing unit (9) is adapted to configure the power supply means (28) between at least one active condition, wherein the bypass circuit (27) is deactivated and the load sharing circuit (25) is activated and supplies the control means (29), and at least one home configuration, wherein the load sharing circuit (25) is deactivated and the bypass circuit (27) is activated and

supplies said processing unit (9).

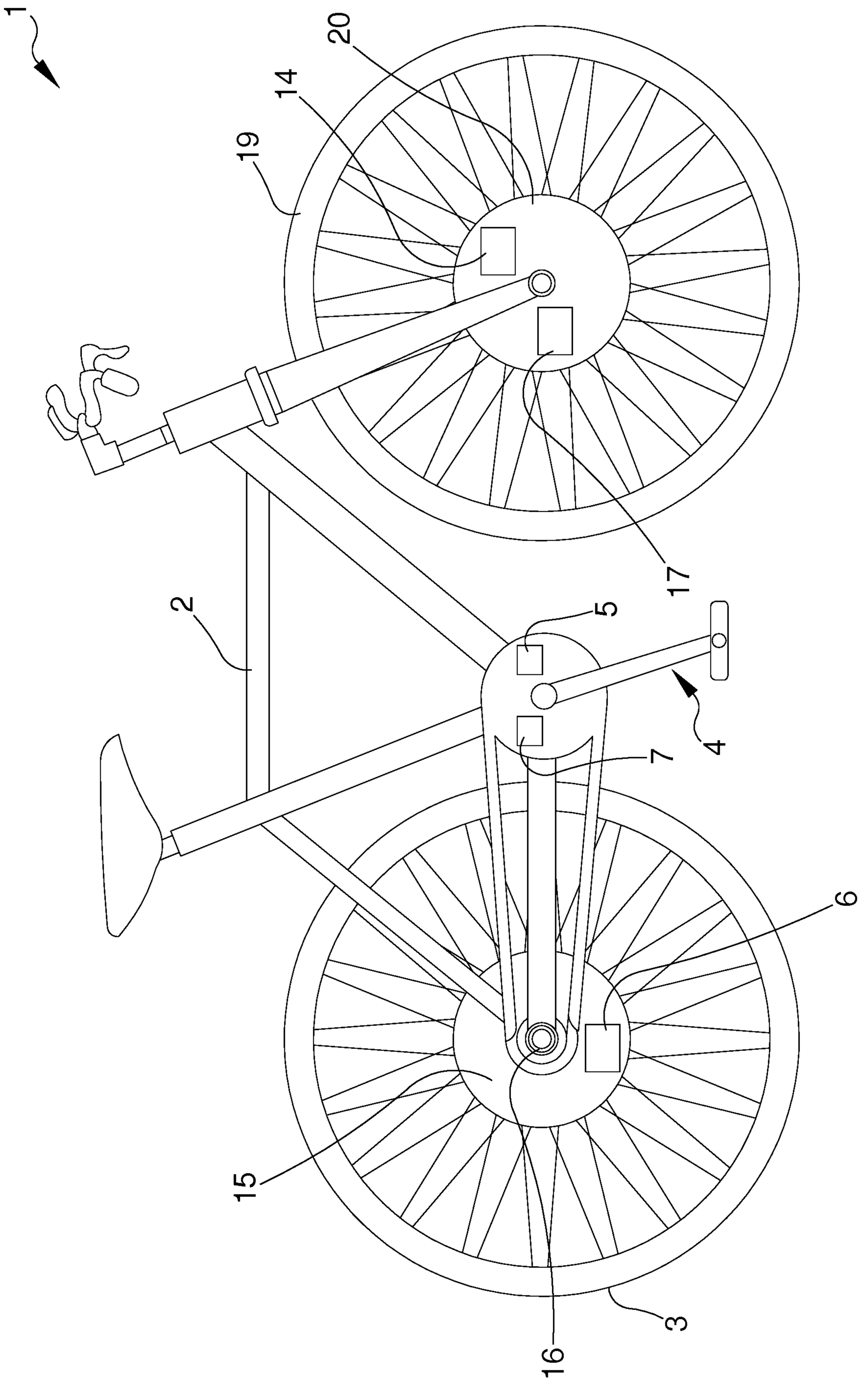


Fig.1

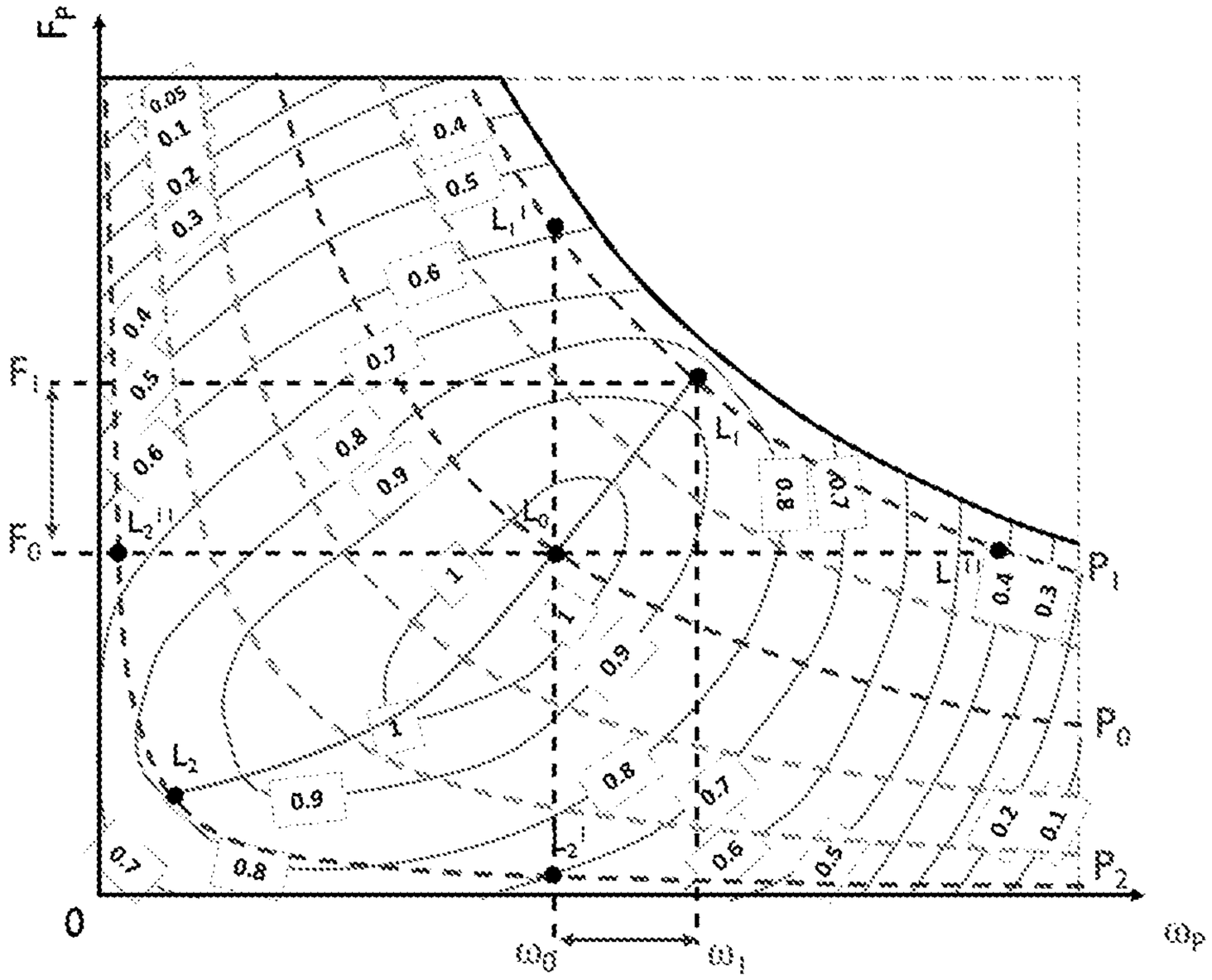

F_φ
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
L_1
L_2
L_0
ε_1
ε_0
φ_1
φ_0
φ_2
0
ω_0
ω_1
ω_p

Fig.2

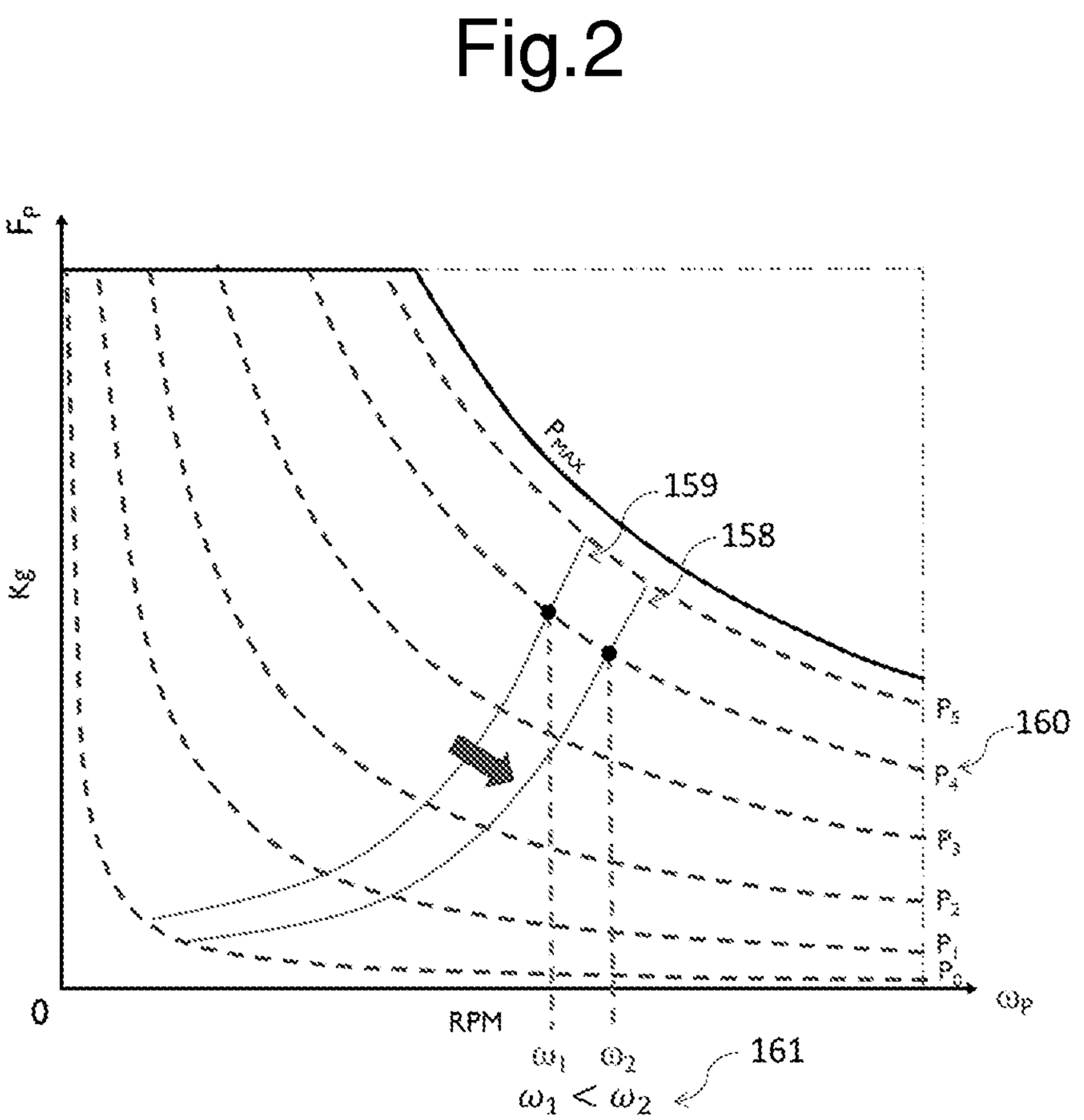

F_φ
K_ε
P_{MAX}
159
158
160
161
P_{ε_1}
P_{ε_2}
P_{ε_3}
P_{ε_4}
P_{ε_5}
P_{ε_6}
0
RPM
ω_p
ω_1 ω_2
$\omega_1 < \omega_2$

Fig.3

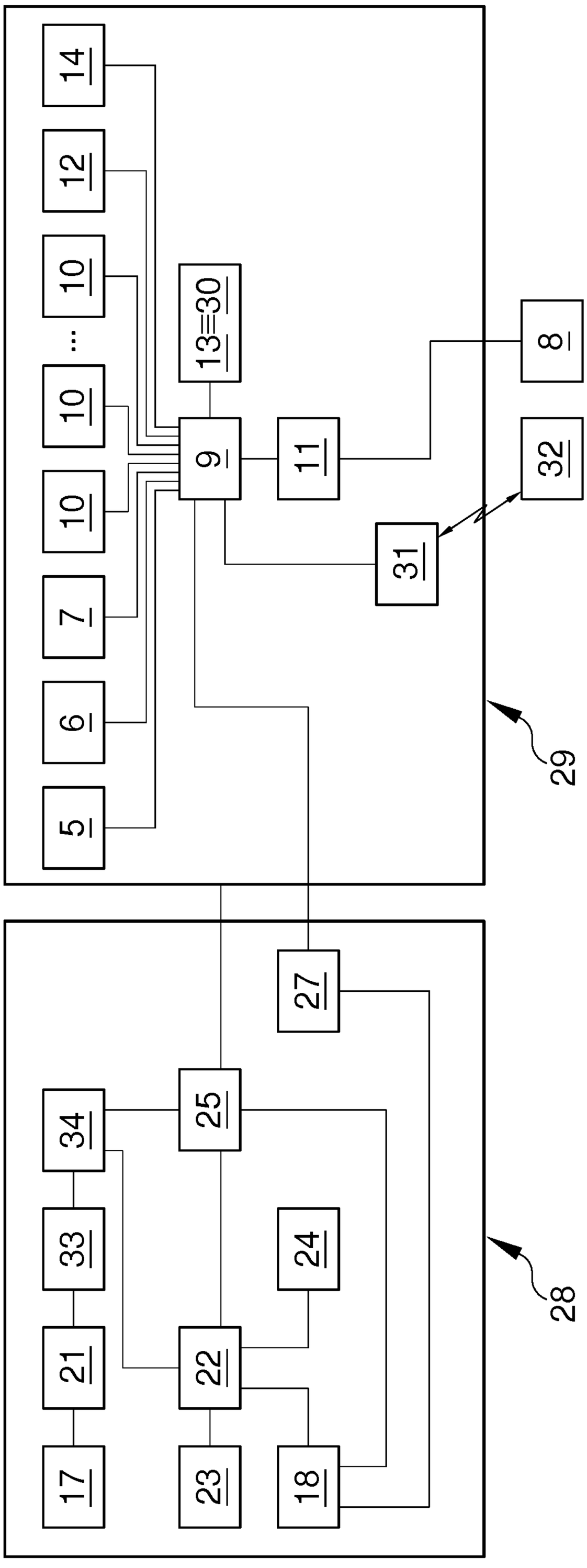

14
12
10
...
10
13=30
10
9
11
8
10
32
7
31
6
5
29
27
34
25
33
24
21
22
17
23
18
28

Fig.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/062097

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62M11/04 F16H15/04 F16H15/50
ADD.

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)
B62M F16H

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.
X	WO 2017/197029 A1 (FALLBROOK IP CO LLC [US]) 16 November 2017 (2017-11-16) the whole document	1-20
X	WO 2014/172422 A1 (FALLBROOK IP CO LLC [US]) 23 October 2014 (2014-10-23) the whole document	1-20
X	US 2018/215432 A1 (SHIMANO CORP) 2 August 2018 (2018-08-02) the whole document	1-20
X	US 2019/301598 A1 (SONENTHAL AVRAHAM [US]) 3 October 2019 (2019-10-03) the whole document	1-20

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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
5 March 2021	12/03/2021
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Baeza Félez, Lluís

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2020/062097

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2017197029 A1	16-11-2017	CN 109477572 A	15-03-2019
		EP 3455525 A1	20-03-2019
		TW 201811617 A	01-04-2018
		US 2017327184 A1	16-11-2017
		US 2018327050 A1	15-11-2018
		WO 2017197029 A1	16-11-2017
WO 2014172422 A1	23-10-2014	CA 2909565 A1	23-10-2014
		CN 105324299 A	10-02-2016
		CN 109018173 A	18-12-2018
		EP 2986494 A1	24-02-2016
		JP 6660876 B2	11-03-2020
		JP 2016516633 A	09-06-2016
		KR 20150144770 A	28-12-2015
		TW 201446584 A	16-12-2014
		TW 201819244 A	01-06-2018
		US 2016040763 A1	11-02-2016
		US 2017276217 A1	28-09-2017
		WO 2014172422 A1	23-10-2014
US 2018215432 A1	02-08-2018	CN 108372900 A	07-08-2018
		DE 102018100918 A1	02-08-2018
		JP 6705760 B2	03-06-2020
		JP 2018122666 A	09-08-2018
		TW 201829247 A	16-08-2018
		US 2018215432 A1	02-08-2018
US 2019301598 A1	03-10-2019	NONE	