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

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
19 March 2020 (19.03.2020)

WIPO | PCT

(10) **International Publication Number**
WO 2020/053760 A1

(51) **International Patent Classification:**
B62M 9/123 (2010.01) *B62M 9/133* (2010.01)

(21) **International Application Number:**
PCT/IB2019/057620

(22) **International Filing Date:**
10 September 2019 (10.09.2019)

(25) **Filing Language:** Italian

(26) **Publication Language:** English

(30) **Priority Data:**
102018000008502 11 September 2018 (11.09.2018) IT

(71) **Applicants: E-NOVIA S.P.A.** [IT/IT]; Via San Martino 12, 20122 Milano MI (IT). **POLITECNICO DI MILANO** [IT/IT]; Piazza Leonardo da Vinci 32, 20133 Milano MI (IT).

(72) **Inventors: BONIOLO, Ivo Emanuele Francesco**; Via Comasinella 97, 20813 Bovisio Masciago MB (IT). **CEREDA, Gianmarco**; Via Timavo 150, 20099 Sesto San Giovanni MI (IT). **CHIAPPA, Simome**; Via Manzoni 3, 23899 Robbiate LC (IT). **SPELTA, Cristiano**; Via Ornago 15, 20882 Bellusco MB (IT). **CORNO, Matteo**; Via Marco Tullio Tirone 5, 20134 Milano MI (IT). **SAVARESI, Sergio Matteo**; Largo Paolo Sarpi 8, 26100 Cremona CR (IT). **MARELLI, Stefano**; Via Giovanni Pascoli 9, 22070 Grandate CO (IT).

(74) **Agent: BARBARO, Gaetano**; Società Italiana Brevetti S.p.A., Via Carducci 8, 20123 Milano MI (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,

(54) **Title:** SYSTEM AND METHOD TO AUTOMATICALLY CHANGE TRANSMISSION OF A BICYCLE

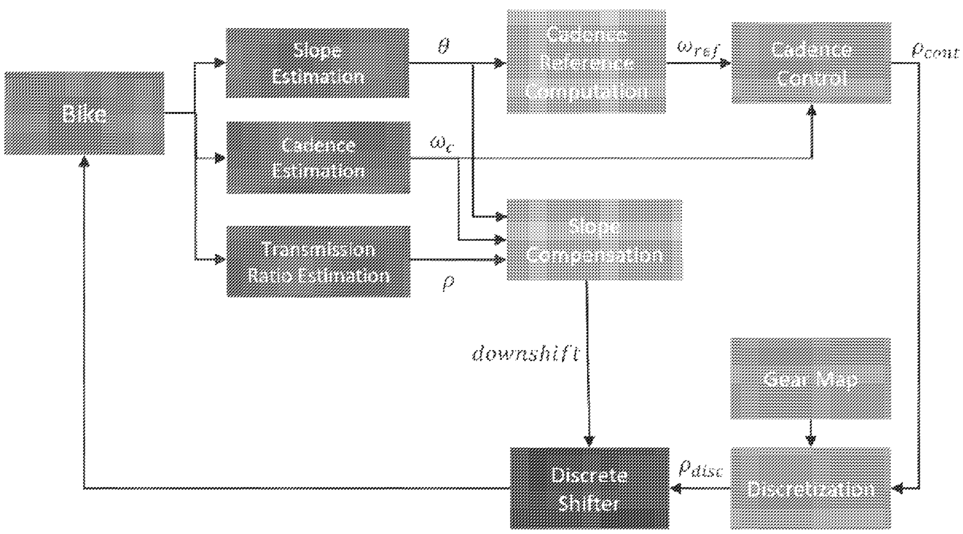

FIG. 2

(57) **Abstract:** A system for automatically changing the transmission ratio of a bicycle includes a rotation frequency sensor of the pedals of the bicycle, that is the pedaling cadence, an acceleration sensor fixed to the frame of the bicycle which indicates the angle of inclination in the direction of advancement of the bicycle with respect to a horizontal plane, a sensor or torque estimator functionally mounted on the bicycle to provide a torque signal representative of a resistant torque acting on the pedals of the bicycle, a non-volatile memory which contains a table for consulting reference values of the rotation frequency of the pedals (pedaling cadence) in function of values of the angle of inclination of the advancement direction, as well as a control unit in communication with the frequency sensor, the torque sensor or estimator and the acceleration sensor and with the non-volatile memory, configured to: read from the memory a reference value of the rotation frequency of the pedals using as input the angle of inclination detected by the sensor, compare the

WO 2020/053760 A1

[Continued on next page]

HR, HU, ID, IL, IN, IR, IS, 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, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, 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, 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*

effective frequency of rotation of the pedals with the reference value read from the memory, and automatically increase or reduce the ratio of transmission of the bicycle according to said comparison and to said value of resistant torque on the pedals of the bicycle, so as to adjust the pedaling cadence required to the cyclist with the reference value of the rotation frequency read by the non-volatile memory and of the resistant torque value on the bicycle pedals. A method for automatically changing a transmission of a bicycle is also disclosed.

SYSTEM AND METHOD TO AUTOMATICALLY CHANGE TRANSMISSION OF A BICYCLE

TECHNICAL FIELD

The present disclosure relates to bicycle transmissions and more particularly to a system, which can be installed on a bicycle, to automatically change a transmission of the bicycle, and a related method.

TECHNOLOGICAL BACKGROUND

Nowadays bicycles are equipped with transmissions with an increasing number of gears, so that the cyclist can adapt in an increasingly finer manner the transmission ratio to the effort that wishes to do.

Transmissions generally allow either to establish the transmission ratio to a selected value in a discrete set of values, or to vary between two limit values practically without solution of continuity the transmission ratio between a drive shaft and a shaft driven by the transmission. Such transmissions are commonly called continuously variable transmissions. A continuously variable gearbox suitable for a bicycle is described in application WO2017/093965.

Both if the bicycle is equipped with a transmission that can assume discrete values, or has an infinite variation transmission, the transmission ratio change can be done manually by the cyclist, moving a lever, or it can be done automatically by a control unit that monitors some parameters to adjust the transmission ratio for optimal pedaling.

Regardless of the fact that the bicycle has a discrete transmission rather than an infinite variation, there is a problem of adapting the transmission ratio so as to allow the user the best performance as road conditions change. Typically, this was done manually by the cyclist who relied on his experience to decide when to change the transmission ratio to maintain maximum performance.

More recently, systems have been developed for automatically changing a transmission of a bicycle, which for example monitor the resistance torque to the pedals so as to reduce or increase the transmission ratio depending on the detected torque value. For example, in the documents US2017/0225742 and US2017/0343105 automatic systems and methods for controlling the transmission ratio of a bicycle are disclosed, equipped with sensors for advancing the speed of the bicycle and a control unit for varying the transmission ratio in a way to keep constant the rotation frequency of the bicycle pedals (pedaling cadence).

SUMMARY

Tests carried out by the applicant have shown that cyclists achieve optimal performance not when they keep constant the pedaling cadence, but when the pedaling cadence is made to vary according to the motion conditions, such as: inclination of the ground, type of terrain, force applied to the pedals. To this end, according to the present disclosure, the bicycle is equipped with a system for automatically changing the transmission ratio having a rotation frequency sensor for the pedals of the bicycle, i.e. the pedaling cadence, an acceleration sensor fixed to the frame of the bicycle which indicates the angle of inclination of the direction of advancement of the bicycle with respect to a horizontal plane, a torque sensor or estimator functionally mounted on the bicycle to provide a torque signal representative of a resistant torque acting on the pedals of the bicycle, a non-volatile memory which contains a reference table of reference values for the frequency of rotation of the pedals (pedaling cadence) as a function of values of the angle of inclination of the direction of advancement, as well as a control unit in communication with the frequency sensor, the torque sensor or estimator and the acceleration sensor and with the non-volatile memory, configured to: read from the memory a reference value of the rotation frequency of the pedals using as an input the angle of inclination, comparing the actual rotation frequency of the pedals with the reference value read from the memory, and automatically increase or reduce the transmission ratio of the bicycle according to the result of said comparison and of the value of resistant torque on the pedals of the bicycle, so as to adjust the pedaling cadence required to the cyclist with the reference value of the rotation frequency read from the non-volatile memory and of the value of resistant torque on the pedals of the bicycle.

According to one aspect, the memory will contain a table of reference values of the pedaling cadence which will be decreasing as the angle of inclination of the direction of advancement with respect to a horizontal plane increases, and with the increase of the resistant torque.

It is also disclosed a method for automatically changing a transmission of a bicycle implemented by the system of this disclosure, so that the pedaling cadence of the cyclist tracks the variable trend of the respective reference value when the inclination of the followed direction of advancement varies, and when the resistant torque acting on the bicycle pedals varies.

The claims as filed are an integral part of this disclosure and are herein incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a diagram of a system according to an aspect of the present disclosure for automatically changing a transmission of a bicycle.

Figure 2 illustrates a control loop for implementing a method according to an aspect of the present disclosure for automatically changing the transmission ratio of a bicycle equipped with a discrete transmission.

Figure 3 shows optional functional blocks to anticipate a reduction of the transmission ratio when the angle of inclination of the direction of advancement of the bicycle and/or of a resistant torque on the pedals exceeds a respective threshold value.

Figure 4 shows a control loop of the frequency of rotation of the pedals of the bicycle.

Figure 5 illustrates a basic control loop for implementing a method according to an aspect of the present disclosure for automatically changing the transmission ratio of a bicycle equipped with an infinite variation transmission.

Figure 6 is a graphical representation of test results for identifying reference values of the rotation frequency of the pedals as a function of the angle of inclination with respect to a horizontal plane of the direction of advancement of the bicycle.

Figure 7 is a graphical representation of test results to identify reference values of the rotation frequency of the pedals as a function of the resistant torque on the pedals of the bicycle.

DETAILED DESCRIPTION

According to one aspect, a scheme of a system for automatically changing the transmission ratio of the gearbox of a bicycle is illustrated in Figure 1, regardless of whether the transmission is a discrete transmission or an infinite variation transmission. The meaning of the represented functional blocks is summarized in the following table:

SPEED SENSOR	Bicycle speed sensor of the advancement speed
POWER METER	Power sensor of power developed on the pedals
CADENCE SENSOR	Pedal rotation frequency sensor (pedaling cadence)
ENCODER	Encoder to detect the rotor position of the electric motor that changes the transmission ratio
WHEEL	Bicycle wheel
PEDALS	Bicycle pedals
IMU	Inertial sensor
CVT / DISCRETE SHIFTER	Continuous or discrete transmission
MOTOR	Electric motor to change the transmission ratio
ECU	Microprocessor control unit
GEAR MAP	Table of available gear ratios
BATTERY	Electric power supply accumulator

According to one aspect, the advancement speed sensor SPEED SENSOR and the power sensor developed on the pedals POWER METER can be omitted.

According to one aspect, the sensors are connected via CAN BUS to the control unit ECU or communicate in a wireless fashion, for example via a ANT protocol.

The ECU control unit has a microprocessor that runs a software code that allows:

- to process data received from the various sensors distributed on the bike;
- on the basis of the available data, to estimate the variables necessary for the implementation of the control algorithms;
- to calculate the optimal cadence reference based on the cyclist's "work" conditions;
- to find the ideal transmission ratio to guarantee the best performance of the cyclist;
- to determine the command to be sent to the electric motor for the implementation of the electronic gearbox.

According to one aspect, a method of this disclosure, applicable to a bicycle with a discrete transmission gearbox, performs the loop shown in Figure 2 to automatically change the transmission ratio. The functional blocks shown in the figure have the following meaning:

BIKE	Bicycle
SLOPE ESTIMATION	Inclination angle detection
CADENCE ESTIMATION	Detection of pedaling cadence
TRANSMISSION RATIO ESTIMATION	Checking the current transmission report
CADENCE REFERENCE COMPUTATION	Determination of a reference value of the rotation frequency of the pedals (pedaling cadence)
SLOPE COMPENSATION	Anticipation of the reduction of the transmission ratio
DISCRETE SHIFTER	Discrete variation of the transmission ratio
CADENCE CONTROL	Determination of a corrective value of the transmission ratio
GEAR MAP	Table of available gear ratios
DISCRETIZATION	Discretization function

Using the IMU inertial sensors and the frequency sensors CADENCE SENSOR mounted on the bicycle, the angle of inclination θ of the bicycle with respect to a horizontal plane and the frequency ω_c of pedaling are sensed, respectively. According to the inclination angle θ, a corresponding reference value ω_{ref} of the pedaling frequency is read from a look-up table loaded in a non-volatile memory of the microprocessor control unit ECU. Knowing the pedaling frequency ω_c and the respective reference value ω_{ref}, according to an aspect of this disclosure the microprocessor control unit ECU determines a control value ρ_{cont} of the transmission ratio so as to induce the user to pedal with the reference cadence ω_{ref}. Since the gearbox has a discrete transmission and not an infinite variation transmission, this control value ρ_{cont} must be discretized, compatibly with the table GEAR MAP of the available transmission ratios, to choose the available discrete transmission ratio ρ_{disc} that best approximates the desired control value ρ_{cont}.

According to one aspect, the functional SLOPE COMPENSATION block allows to anticipate the reduction of the transmission ratio, by issuing a *downshift* command, as soon as a climb starts and/or when the resistant torque on the pedals exceeds a respective threshold value.

The operations performed in the functional block SLOPE COMPENSATION are illustrated in figure 3. The inclination angle θ detected by the inertial sensor is compared with an inclination threshold, which for example can be equal to 1.5 degrees, and a *binaryθ* flag is generated which assumes an active logic value when the inclination threshold is exceeded. Starting from a dynamic model of the bicycle, with a torque estimator TORQUE ESTIMATION it is possible to estimate, in a manner known to skilled persons, a resistant torque Tc to the pedals of the bicycle according to the angle of inclination θ, to the frequency ω_c of pedaling and of the current transmission ratio ρ. When the estimated resistive torque Tc exceeds a respective predetermined torque threshold and/or when the flag *binaryθ* takes an active logic value, the block COMPENSATION generates the command *downshift* to scale down the gear.

As an alternative to the estimator TORQUE ESTIMATION of the resistant torque Tc to the pedals, it is possible to install a resistant torque sensor functionally connected to the pedals or a power sensor of power developed on the pedals and a speed sensor, in order to obtain, either by direct measurement or by extrapolation, an estimate of the resistant torque Tc to the pedals.

Figure 4 illustrates the full control loop of the pedaling cadence, as performed in the diagram of Figure 2. According to one aspect, the control algorithm acts as follows:

- a cadence reference is generated according to one of the proposed arrangements (for example depending on the slope of the road or of the resistant torque to the pedals);
- the reference is compared with the current cadence measurement to derive the error;
- on the basis of the error the transmission ratio to be implemented is determined to reduce the deviation of the reference from the measured rotation frequency of pedals.

Once the transmission reference is generated, it is necessary to determine which of the available discrete ratios allows to minimize the deviation from the reference value, which represents the optimum. This is done on the basis of a shift map that defines in the two possible directions (decreasing - down shifting, and increasing - up shifting) how the electronic gearbox should be controlled. The output of the discrete gearbox thus generates two possible commands (up-shift / down-shift) which are supplied by the controller to the electronic gearbox.

Figure 5 shows the control loop according to an aspect of the present disclosure in the case of a bicycle equipped with an infinite variation transmission CVT. The functional blocks bearing the same labels as the functional blocks of Figure 2 perform the same operations. Unlike the diagram in figure 2, there is not the block SLOPE COMPENSATION to anticipate the reduction of the transmission ratio, because the infinite variation transmission CVT immediately reduces the transmission ratio so as to make it match to the desired value ρ.

Cadence control is a classic reference tracking and error minimization control:

- The controlled variable is the user's pedaling cadence;
- the control variable is represented by the transmission ratio to be commanded to the electronic gearbox in order to keep the user's cadence as close as possible to the pedaling reference.

The control system (adjustable according to the chosen type of pedaling feeling) allows to determine a change directly proportional to:

- The deviation of the current cadence value from the reference;
- The integral of the cadence error, which guarantees the cancellation of the error when the transient is over;
- The derivative of the cadence error, guaranteeing a more "ready" change with respect to a variation of the reference (and therefore of the working conditions).

The transmission value ρ generated by the cadence control determines a position that the motor MOTOR should take to change the transmission ratio of the continuous variation transmission.

The reference values ω_{ref} of the rotation frequency of the pedals (pedaling cadence) is established by the ECU control unit in order to guarantee the best performance and feeling to the user, and in general it is a variable reference calculated automatically as conditions change.

Analyzing test data carried out by professional cyclists, some possible relationships between the pedaling cadence independently exercised by the cyclist during races (with traditional change) with respect to some of the variables monitored during the surveys were highlighted. The results of these tests are represented graphically in Figures 6 and 7. Two possible ways of generating the cadence reference are highlighted:

1. The optimal cadence varies according to the slope of the road θ (figure 6). From the data collected it is possible to identify a straight line of linear variation or a curve that defines a direct relationship between the slope angle of the road and the ideal pedaling cadence that the cyclist should keep. It should be noticed that the optimum frequency in general is not constant, but varies to ensure to the cyclist the best working efficiency.
2. It is possible to select any work area (depending on the inclination θ) in which a direct relationship is identified between the torque supplied by the cyclist (figure 7) and the optimal cadence reference.

Depending on the chosen mode, it is possible to obtain the reference of optimal cadence either by means of an explicit relation or thanks to single / double input look-up tables, read by the microprocessor of the ECU control unit.

CLAIMS

1. A system for automatically changing a transmission ratio of a bicycle transmission, including:

a rotation frequency sensor, functionally mounted on the bicycle to provide a frequency signal representative of an effective rotation frequency of bicycle pedals;

an inertial sensor fixed to a bicycle frame, configured to generate an inclination signal representative of an angle of inclination of a forward direction of advancement of the bicycle with respect to a horizontal plane;

a torque sensor or estimator functionally mounted on the bicycle and configured to provide a torque signal representing a value of a resistant torque that acts on the bicycle pedals;

a control unit connected to the frequency sensor, to the torque sensor or estimator and to the inertial sensor, configured to receive said frequency signal, said torque signal and said inclination signal;

a non-volatile memory functionally connected to the control unit, the memory containing at least a look-up table of reference values of the rotation frequency of said pedals as a function of values of the inclination angle of the forward direction of advancement;

wherein said control unit is configured for:

- reading from said memory a reference value of the rotation frequency of the pedals using as entry a value of said inclination angle represented by the inclination signal,
- carrying out a comparison of said effective rotation frequency of the pedals with said reference value of the rotation frequency read from the memory,
- automatically increasing or reducing a transmission ratio of said bicycle transmission as a function of said comparison and of said value of resistant torque on the bicycle pedals.

2. The system according to claim 1, wherein said memory contains said look-up table with decreasing reference values of the rotation frequency as the values of the inclination angle of the feed direction increase.

3. The system according to claim 1 or 2, wherein said control unit is configured to reduce said transmission ratio when said value of resistant torque exceeds a respective

threshold value.

4. The system according to claim 1 or 2, wherein said look-up table contains said reference values of rotation frequency of said pedals as a function of values of the angle of inclination of the forward direction of advancement and of values of said resistant torque.

5. The system according to one of the preceding claims, further comprising a speed sensor functionally mounted on the bicycle to provide a speed signal representative of a bicycle advancement speed, said control unit being connected to the speed sensor to receive said speed signal, and being configured to automatically increase or reduce a transmission ratio of said bicycle transmission as a function of the bicycle advancement speed.

6. A method for automatically changing a transmission ratio of a bicycle transmission, comprising the following operations:

sensing an effective rotation frequency of bicycle pedals;

sensing an angle of inclination of a forward direction of advancement of the bicycle with respect to a horizontal plane;

sensing or estimating a value of resistant torque on the bicycle pedals;

reading, from a look-up table of reference values of the rotation frequency of said pedals as a function of the angle of inclination of the forward direction of advancement, a reference value of the rotation frequency of the pedals using as entry a value of said angle of inclination;

performing a comparison between said effective rotation frequency of the pedals and said reference value of the rotation frequency read from the memory;

automatically increasing or reducing a transmission ratio of said bicycle transmission as a function of said comparison and of said value of resistant torque on the bicycle pedals.

7. The method according to claim 6, further comprising the operations of:

reading, from said look-up table of reference values of the rotation frequency of said pedals as a function of values of the angle of inclination of the direction of advancement and of values of said resistant torque, a reference value of the rotation frequency of the pedals using as entries a value of said angle of inclination and a value of said resistant torque.

8. The method according to claim 6, comprising the following operations:

comparing said estimated resistant torque value with a resistant torque threshold;

comparing said value of the inclination angle with an inclination threshold;

reducing the transmission ratio if at least one value between the value of the resistance torque and the value of the angle of inclination exceeds the respective threshold.

9. The method according to one of claims from 6 to 8, comprising the following steps:

estimating said value of resistant torque on the bicycle pedals in function of a current transmission ratio, of the effective rotation frequency of the bicycle pedals and of said value of the inclination angle.

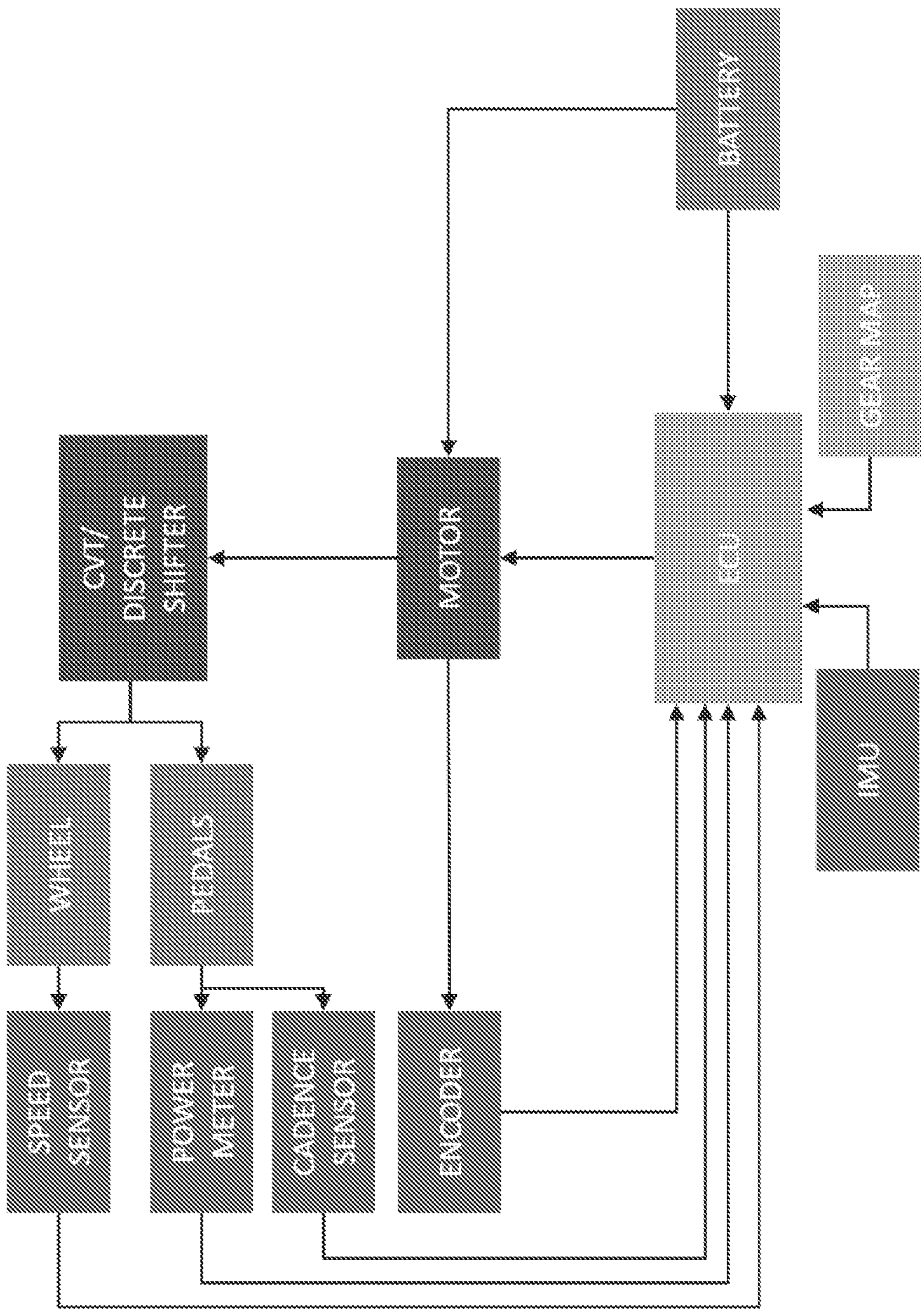
BATTERY
GEAR MAP
CVT/
DISCRETE
SHIFTER
MOTOR
ECU
IMU
WHEEL
PEDALS
SPEED
SENSOR
POWER
METER
CADENCE
SENSOR
ENCODER

FIG. 1

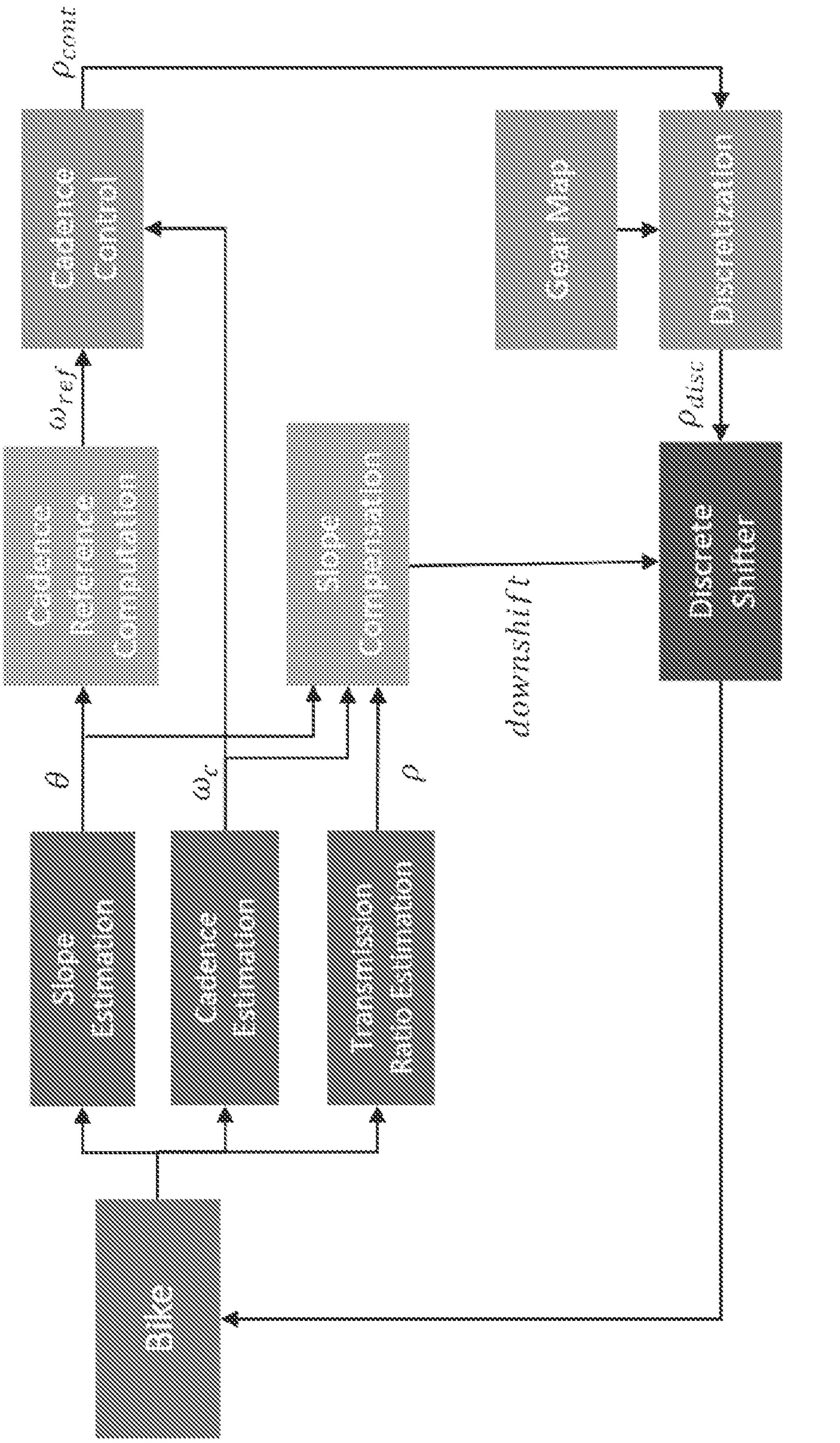
Bike
Slope Estimation
Cadence Estimation
Transmission Ratio Estimation
θ
ω_c
ρ
Cadence Reference Computation
Slope Compensation
ω_{ref}
Cadence Control
ρ_{cont}
Gear Map
Discretization
ρ_{disc}
$downshift$
Discrete Shifter

FIG. 2

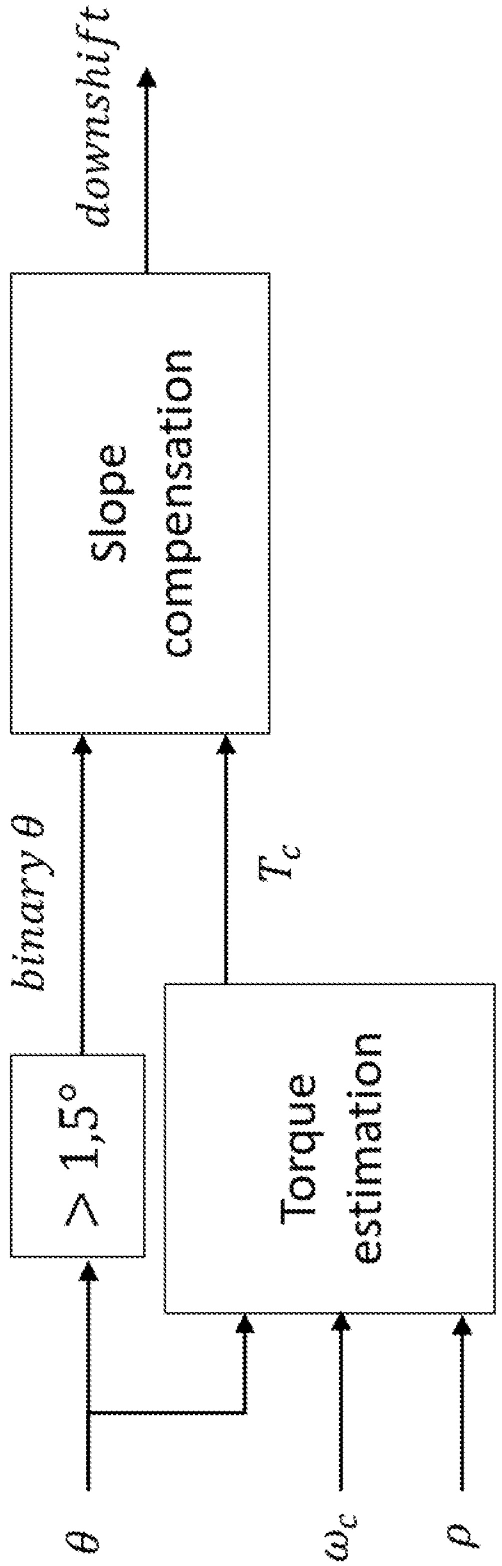
$downshift$
Slope compensation
$binary\,\theta$
T_c
$> 1{,}5°$
Torque estimation
θ
ω_c
ρ

FIG. 3

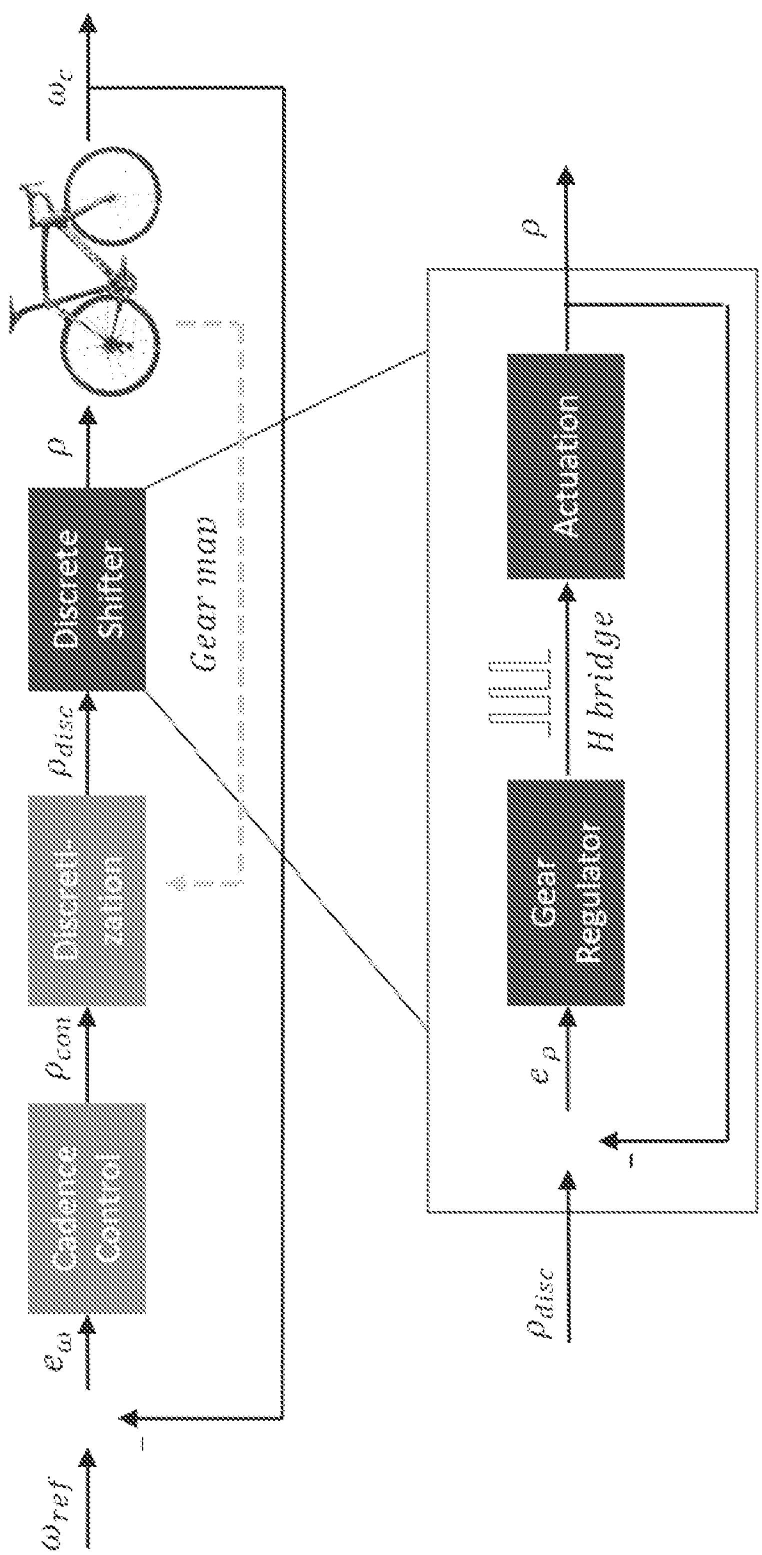
ω_c
ρ
Discrete Shifter
ρ_{disc}
Discreti-zation
ρ_{con}
Cadence Control
e_ω
ω_{ref}
−
Gear map
ρ
Actuation
H bridge
Gear Regulator
e_ρ
−
ρ_{disc}

FIG. 4

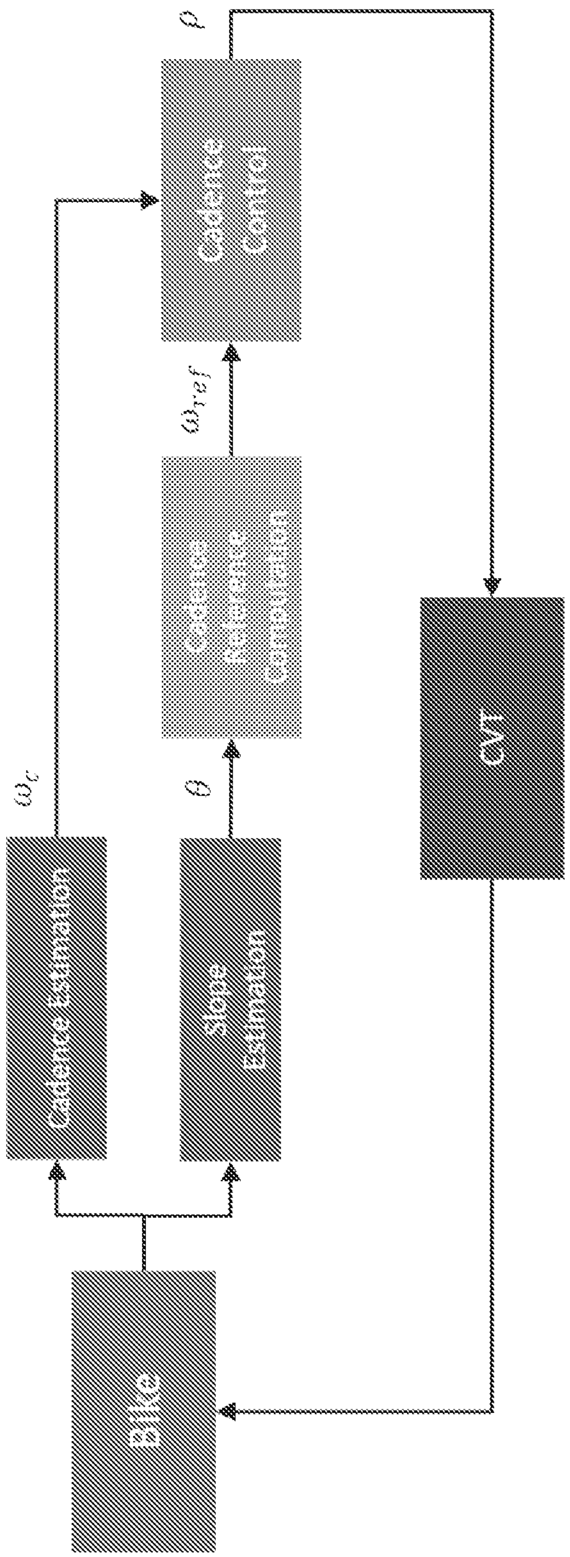
Bike
Cadence Estimation
Slope Estimation
ω_c
θ
Cadence Reference Computation
ω_{ref}
Cadence Control
ρ
CVT

FIG. 5

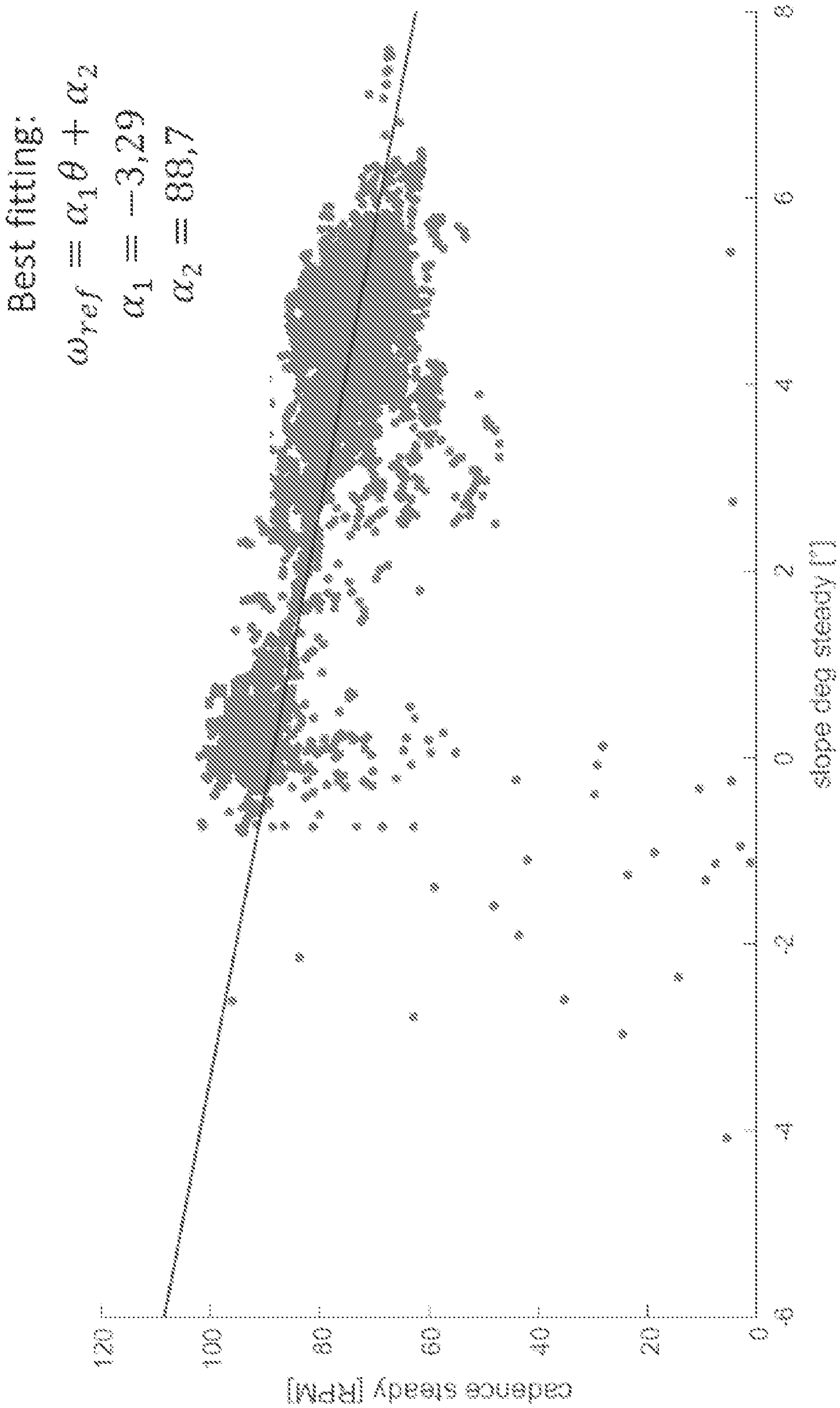
Best fitting:
$\omega_{ref} = \alpha_1\theta + \alpha_2$
$\alpha_1 = -3{,}29$
$\alpha_2 = 88{,}7$
cadence steady [RPM]
0
20
40
60
80
100
120
-6
-4
-2
0
2
4
6
8
slope deg steady [°]

FIG. 6

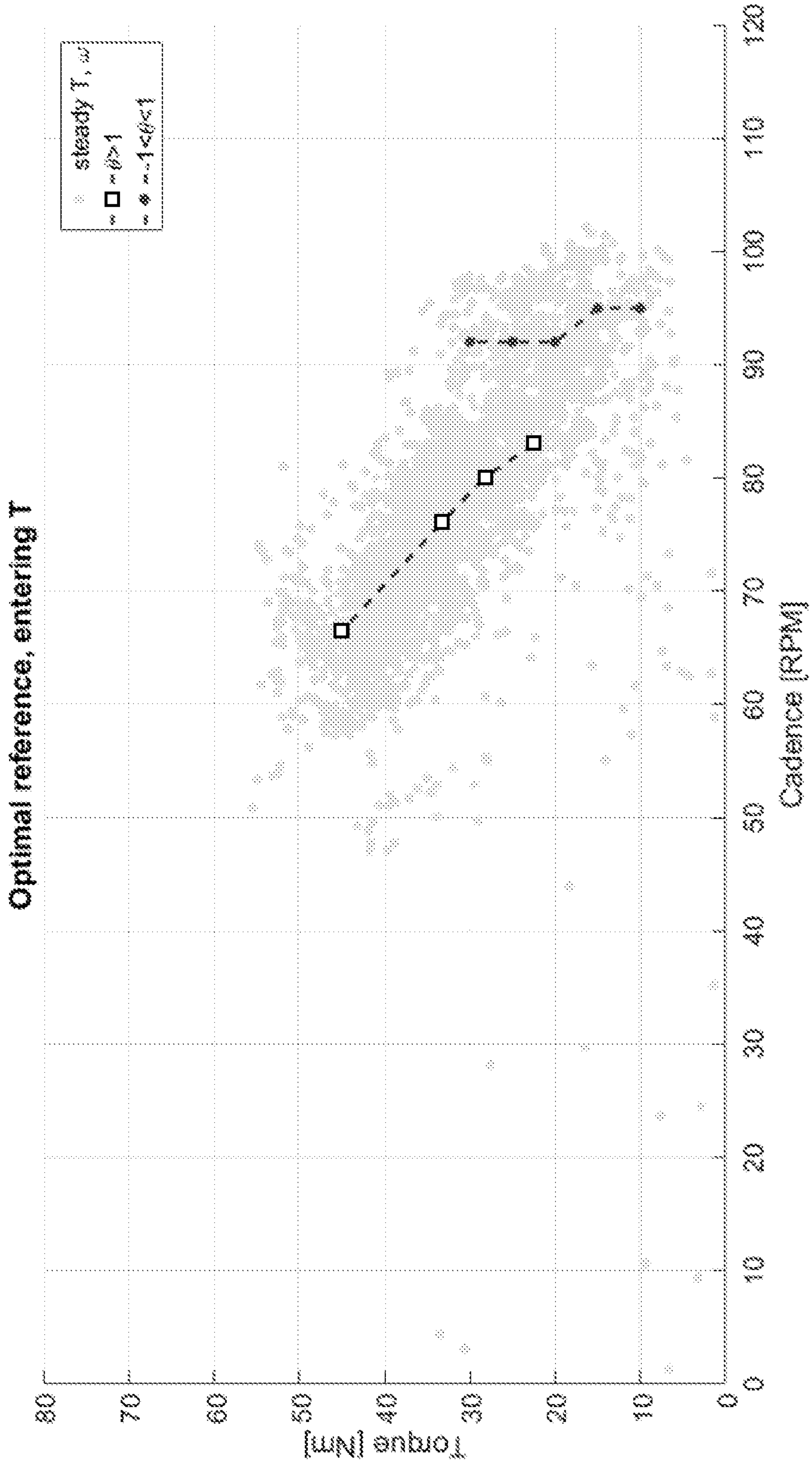
Optimal reference, entering T
steady T, ω
θ>1
-1<θ<1
Torque [Nm]
Cadence [RPM]
0
10
20
30
40
50
60
70
80
90
100
110
120

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/057620

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62M9/123 B62M9/133
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 B62K

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 2012/068265 A1 (CZOYKOWSKI J R) 24 May 2012 (2012-05-24) claims 1,3,8; figures 1-9B	1-9
X	US 6 047 230 A (SPENCER MARC D [US] ET AL) 4 April 2000 (2000-04-04) the whole document	1-9
X	KR 2015 0089997 A (LEE GI YOUNG [KR]) 5 August 2015 (2015-08-05) the whole document	1-9
A	US 2017/334522 A1 (ZAHID SOHAIB [CA] ET AL) 23 November 2017 (2017-11-23) "Automatic Gear Shifting" paragraphs [0191] - [0259]; figures 3,22-31	1-9

-/--

[X] Further documents are listed in the continuation of Box C.

[X] 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
9 December 2019	16/12/2019

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

3

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 314 638 A2 (SHIMANO KK [JP]) 28 May 2003 (2003-05-28) paragraph [0032]; figures 1-12	1-7
A	US 2016/375958 A1 (HASHIMOTO AKINORI [JP] ET AL) 29 December 2016 (2016-12-29) paragraphs [0072], [0076] - [0078], [0084], [0085], [0091] - [0093], [0098]; figures 1-15	1-7

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2019/057620

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012068265 A1	24-05-2012	EP 2640629 A1	25-09-2013
		US 2012130603 A1	24-05-2012
		WO 2012068265 A1	24-05-2012
US 6047230 A	04-04-2000	NONE	
KR 20150089997 A	05-08-2015	NONE	
US 2017334522 A1	23-11-2017	CA 2968322 A1	26-05-2016
		US 2017334522 A1	23-11-2017
		WO 2016079620 A1	26-05-2016
EP 1314638 A2	28-05-2003	CN 1420295 A	28-05-2003
		DE 60221622 T2	28-08-2008
		EP 1314638 A2	28-05-2003
		JP 3644633 B2	11-05-2005
		JP 2003156139 A	30-05-2003
		TW 552365 B	11-09-2003
		US 2003096674 A1	22-05-2003
US 2016375958 A1	29-12-2016	JP 2017007644 A	12-01-2017
		TW 201700347 A	01-01-2017
		US 2016375958 A1	29-12-2016