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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 September 2012 (20.09.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/125165 A1

(51) International Patent Classification:
B62M 6/50 (2010.01) *B62M 11/18* (2006.01)
B62M 6/45 (2010.01) *F16H 3/00* (2006.01)

(21) International Application Number:
PCT/US2011/028686

(22) International Filing Date:
16 March 2011 (16.03.2011)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **SRAM, LLC** [US/US]; 1333 N. Kingsbury St. 4th Floor, Chicago, IL 60642 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **JORDAN, Brian** [US/US]; 4047 N. Damen Avenue, Chicago, IL 60618 (US).

(74) Agent: **SERDYNSKI, Lisa**; SRAM, LLC, 1333 N. Kingsbury St. 4th Floor, Chicago, IL 60642 (US).

(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, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, 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, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, ML, MR, NE, SN, TD, TG).

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

(54) **Title**: BICYCLE MOTOR DRIVE HUB AND MOTOR CONTROLLER

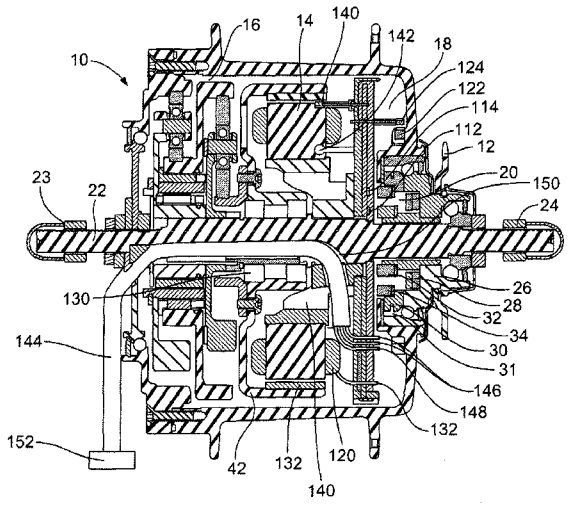


FIG. 1

(57) **Abstract**: A motor drive hub, in particular for a handlebar-steered vehicle, comprises: - a transmission assembly configured to drive the vehicle in forward direction; - an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly, - the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward directions motor controller for controlling the motor, wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on a speed parameter.

WO 2012/125165 A1

Bicycle Motor Drive Hub and Motor Controller

Description

Background of the Invention

The present invention relates to a vehicle wheel drive system and more particularly to a vehicle wheel drive system that includes a motor and a transmission assembly wherein the transmission assembly is configured to provide at least a first forward wheel speed when the motor is rotated in a first direction and at least a second forward wheel speed when the motor is rotated in a second direction. Moreover, the present invention relates to a controller for controlling such a vehicle wheel drive system.

Vehicle wheel drive systems, in particular vehicle wheel drive systems which are used for handlebar-steered vehicles like bicycles, are well-known in the art. Recently, such drive systems have been developed which have an additional motor for providing an assisting force to the driver. Bicycles equipped with such a drive system are called E-bikes. Such a drive system is known from European patent application EP 2 204 316 A1. This documents describes a vehicle wheel drive system that includes a motor and a transmission assembly wherein the transmission assembly is configured to provide at least a first forward wheel speed when the motor is rotated in a first direction and at least a second forward wheel speed when the motor is rotated in a second direction.

Summary of the Invention

It is an object of the present invention to provide a drive system for driving a vehicle wheel in a forward direction at various speeds wherein the drive system provides a smooth activation and a switching operation which is dependent on the actual driving situation.

This object is solved by a motor drive hub, motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,

- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction, and
- a motor controller for controlling the motor,

wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on a speed parameter.

According to the present invention, the direction of rotation of the motor of the motor drive hub is controlled based on a speed parameter related to the motor drive hub. The speed parameter represents the speed of the motor or the speed of an output member of the motor drive hub or the speed of a wheel of the vehicle. The speed parameter can be provided by a speed sensor adapted to determine the speed of the motor or the speed of the output member of the motor drive hub or the speed of a wheel of the vehicle. Alternatively, the speed parameter can be calculated based on at least one operational parameter of the motor drive hub or the vehicle.

The transmission may have one or plural first drive speeds for transmitting a combined drive force from an input driver and the motor to a hub shell via plural different transmission paths when the motor rotates in the first direction and may have one or plural second drive speeds for transmitting a combined drive force from an input driver and the motor to a hub shell via plural different transmission paths when the motor rotates in the second direction. Switching means can be associated to the transmission to choose one of the different first and second drive speeds automatically or by a driver selection.

According to one embodiment of the invention, the motor drive hub further comprises a memory in which a first and second speed parameter threshold value are stored, wherein the motor controller switches the motor from the state in which it rotates in the first direction to the state in which it rotates in the second direction when the speed parameter exceeds said first speed parameter threshold value and wherein the motor controller switches the motor to rotate from the state in which it rotates in the second direction to the state in which it rotates in the first direction when the speed parameter falls below said second speed parameter threshold value. In this embodiment, it is possible according to the invention that the first speed

parameter threshold value is of the same or a higher amount than the second speed parameter threshold value.

According to a further development of the invention, the motor drive hub may further comprise a load sensor for detecting an actual external load applied to the motor drive hub. This load can be applied by a driver applying a driving force on pedals which is transmitted via a chainwheel and a chain and sprocket coupled with an input driver of the motor drive hub. In this regard, it is possible that the motor controller controls a current supply supplied to the motor based on the external load detected by the load sensor.

In one embodiment of the invention, the load sensor comprises a torque sensor coupled to an input driver of the motor drive hub for detecting the external torque applied to the input driver. In particular it is possible that the drive hub includes a drive ring which is coupled to the input driver in a torque transmitting manner by means of a spring arrangement, which spring arrangement deflects to allow a relative movement between the drive hub and the drive ring depending on the actual external torque applied to the input driver. In other words, depending on the actual external load (i.e. torque) applied to the input driver the spring arrangement deflects to as certain degree resulting in a relative movement between the drive hub and the drive ring. The amount of this relative movement can be detected in order to determine the input torque which indicates the external load applied to the input driver. Stops can be provided between the input driver and the drive ring to limit the relative movement in regard to one another.

Moreover, it is possible that the input driver and the drive ring are formed by permanent magnets having at least one magnetic north pole and one south pole on a detection surface, respectively, wherein at least one magnetic sensor is associated to each of the input driver and the drive ring for detecting the actual rotational position thereof, respectively. Thereby the angular position of the magnetic input driver and the magnetic drive ring can be determined based on a phase shift of the output signals of the magnetic sensors. In particular, the at least one magnetic sensor is formed by a Hall sensor or a Reed sensor. However also other types of magnetic sensors can be used.

Based on the signals received from the magnetic sensors providing indications on the actual relative position of the drive ring and the input driver the motor controller

uses a pulse width modulation scheme to control the current supply supplied to the motor.

As an alternative to a control based on the speed parameter, the invention relates to a motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,
- a load sensor for detecting an actual external load applied to the motor drive hub, and
- a motor controller for controlling the motor,

wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on the external load detected by the load sensor.

In order to avoid shocks in the motor, the present invention further provides that when switching between the first direction and the second direction the motor is slowed or braked in a braking mode. Moreover, it is possible that the motor is operable in a braking mode in which it functions as a generator.

In a further embodiment of the invention the motor is deactivated if the vehicle or the motor drive hub or the input driver is moved in a backward direction.

The motor drive hub according to the invention may further comprise a thermal sensor for monitoring the temperature of the motor, wherein the motor is controlled depending on the actual temperature detected by the thermal sensor.

The invention further relates to a motor controller for controlling a motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;

- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,

wherein the motor controller switches the motor between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on a speed parameter .

As an alternative, the invention relates to a motor controller for controlling a motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,
- a load sensor for detecting an actual external load applied to the motor drive hub,

wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on the external load detected by the load sensor.

Brief Description of the Drawings

In the drawings:

Fig. 1 is a cross-sectional view of a vehicle drive system;

Fig. 2 is a partial cross-sectional view of the drive system shown in fig. 1;

Fig. 3 is a cross-sectional view taken along line A-A of fig. 2;

Fig. 4 is a cross-sectional view taken along line B-B of fig. 2;

Fig. 5-7 are different signal lines provided by the first and second hall sensors in different driving situations;

Fig. 8 is a cross-sectional view similar to fig. 1;

Fig. 9 is a cross-sectional view taken along line C-C of fig. 2 in a first state;

Fig. 10 is a cross-sectional view taken along line C-C of fig. 2 in a second state; and

Fig. 11 is a side view of a bicycle including a vehicle wheel drive system according to one embodiment of the present invention.

Detailed Description

The bicycle motor drive hub of the present invention is shown in Figure 1 and has the reference number 10. The drive hub 10 is adapted to be mounted to the rear wheel 202 of a bicycle 200 (Fig. 11) and includes a drive sprocket 12 to be connected to a front crankset 204 by a chain 206 , belt, or other means. The drive hub 10 includes a motor 14, a gear reduction transmission 16, a motor controller 18, and an input torque sensor 20.

The drive system 10 may be used on other types of handlebar-steered wheeled vehicles such as scooters and tricycles, and on other types of wheeled vehicles such as cars. The wheel hub 10 includes a hub axle 22 non-rotatably mountable to a frame 205 of the bicycle 200 and a hub shell 36 that encloses the electric motor 14 and the transmission assembly 16. The hub shell 20 includes outer flanges having holes to receive ends of spokes 203 that connect the hub shell 36 to an outer rim 207 of the bicycle wheel 202. Roller bearings are disposed between the hub shell 36 and the hub axle 22.

The drive hub 10 includes an axle 22 and axle nuts 23, 24; the axle nuts 23, 24 being used to attach the drive hub 10 to the rear fork of a bicycle frame. The drive

sprocket 12 is coupled to an input driver 26 by spines and is secured with a wire ring or other means. A drive spring 28 is disposed between stops 27, 29 of the input driver 26 and a drive ring 30. A one-way clutch 31 is disposed between the drive ring 30 and a hub shell 36. A first magnet ring 32 is coupled to rotate with the input driver 26; a second magnet ring 34 is coupled to rotate with the drive ring 30. When torque is applied to the drive sprocket 12, the first magnet ring 32 will rotate relative to the second magnet ring 34 due to the deflection of the drive spring 28 disposed between the input driver 26 and the drive ring 30.

The motor 14 is configured to drive the hub shell 36 through a multi-speed transmission. When the motor spins in a first direction it drives the hub shell 36 with a first gear reduction. When the motor 14 spins in a second direction it drives the hub shell 36 with a second gear reduction. The drive hub 10 is also able to spin freely in the forward direction when the motor 14 is off and not rotating.

This drive method is described in detail in the applicant's European patent application EP 2 204 316 A1, the content of which is incorporated by reference in this application.

The transmission 16 is composed of 2 stages, a first stage and a second stage (Fig. 8). The first stage of the transmission 16 is composed of a first sun 40 coupled to the output of the motor 14, which is connected to a rotor 42, a set of first planet gears 44 supported by a first planet carrier 46, the first planet gears 44 being engaged with the first sun 40, a first ring gear 48 engaged with the first planet gears 44, wherein said first planet carrier 46 is fixed to the axle 22 and. The second stage of the transmission 16 is composed of a second sun gear 50 coupled to the first ring gear 48 of the first transmission 16 stage, a set of second planet gears 52 engaged with the second sun gear 50, a second ring gear 54 engaged with the set of second planet gears 52, the second ring gear 54 coupled to drive the hub shell 36, and a second carrier 56 supporting the second planet(s) 52.

The second carrier is 56 coupled to a cam 58. An inner roller clutch 60 is disposed between the cam 58/second carrier 56 and the axle 22; an outer roller clutch 80 is disposed between the cam 58/second carrier 56 and the second sun 50. When the motor 14 operates in a first direction the second stage carrier 56 is locked to the axle 22 and both gear reduction stages are active to provide an overall first gear reduction. When the motor 14 operates in a second direction the second stage

carrier 56 is locked to the second sun 50 effectively making the second stage 1:1 and providing an overall second gear reduction.

Details of the inner roller clutch 60 and outer roller clutch 80 are shown in Fig. 9 and Fig. 10. The inner roller clutch 60 is composed of an inner race 62 formed on a collar 64, said collar 64 is locked to the axle 22, an inner ramp 66 formed on the cam 58, an inner spacer 68 with slots 70 to accept inner rollers 72, and an inner friction element 74 between the inner spacer 68 and the collar 64. As shown in Fig. 9 when the cam 58 is rotated clockwise relative to the collar 64 the inner rollers 72 pushed by the inner spacer 68 and inner friction element 74, will lock the cam 58 to the collar 64 and axle 22.

The outer roller clutch 80 is composed of an outer race 82 formed on the second sun gear, an outer ramp 84 formed on the cam 58, an outer spacer 86 with slots 88 to accept outer rollers 90, and a friction element 92 between the outer spacer 86 and the outer race 82. As shown in Fig. 10 when the second sun gear 50 is rotated anti-clockwise relative cam 58 the outer rollers 90, pushed by the outer spacer 86 and outer friction element 92 will lock the second sun gear to the cam 58.

The cam 58 has a pocket 94 to receive a regulator 96. The regulator 96 has a first arm 98 that abuts a surface on the inner spacer 68 and a second arm 100 that abuts a surface of the outer spacer 86. The regulator 96, inner spacer 68, outer spacer 86, and cam 58 are configured so that the outer clutch and inner clutch can not be locked at the same time. This permits the bicycle to be rolled backwards.

The transmission 16 is configured to allow the bicycle to roll backwards in second gear (the second sun 50 locked to the cam 58). Second gear is a smaller gear reduction and allows the bicycle to be rolled backwards with less effort.

The motor controller 18 contains a motor drive circuit, a microprocessor, memory storage, and a torque sensor 20 circuit. The motor controller 18 can be mounted to a motor stator 110 or the axle 22.

The torque sensor 20 circuit contains a first Hall sensor 112 configured to sense the angular position of the first magnet ring 32 and a second Hall sensor 114 configured to sense the angular position of the second magnet ring 34 (Fig. 2). The face of each magnet ring contains at least one north pole N and one south pole S (Fig. 4). The

poles are offset relative to the hall sensors 112, 114 to produce a quadrature signal (Fig. 5), therefore the motor controller 18 can determine if the crankset is pedaled forwards or backwards (Fig 7). As the rider applies more force to the pedals, more torque is applied to the input sprocket 12 causing the drive spring 28 to deflect. As the drive spring 28 deflects there is a phase shift relative to the two signals of the first and second hall sensors 112, 114. The phase shifts are represented by dimension A and dimension B in Figs. 5 and 6. From these figures it can be seen that with increasing external load the face shift dimensions A and B change.

Although the torque sensor in this embodiment uses magnets and hall sensors to generate a signal, other means could be utilized to generate the signal such as optical sensors, mechanical switches, etc.

The microprocessor compares the phase shift values from the torque sensor circuit to values stored in memory to calculate the amount of assistance the motor 14 will supply to the hub shell 36. The microprocessor sends a signal to the motor control circuit to provide the necessary electrical current to the motor 14. The motor controller 18 uses a pulse width modulation (PWM) scheme to control the current supplied to motor windings 120. Generally the higher the input torque, the larger the deflection of the drive spring 28 and hence the larger the phase shift and more current is supplied to the motor 14.

The motor controller 18 is configured to determine the speed of the hub shell 36. This can be accomplished with a speed magnet 122 coupled to rotate with the hub shell 36. A magnet sensor 124, such as a Hall sensor or Reed switch, is used to measure the period of the wheel rotation and can therefore calculate the rotational speed. Other means could be used to measure the hub shell speed, such as optical sensors or mechanical switches. Alternatively the motor controller could calculate hub speed based on the motor speed and transmission gear ratio, which is known to the controller. The controller contains in memory an upshift speed threshold value and a downshift speed threshold value. When the hub speed is below the downshift speed threshold value the motor 14 operates in a first direction. When the hub speed exceeds the upshift speed threshold value the motor 14 operates in a second direction. Generally the upshift speed threshold value is higher than the downshift speed threshold value; however, they could be the same speed.

When a speed change is desired the motor 14 must change direction. It is desirable that the speed change happens quickly enough that the rider does not notice a significant loss of power. However, if the motor 14 accelerates too quickly a shock load could cause damage to the parts when the motor re-engages with the transmission. When the motor controller 18 determines that it is time to change speeds, the motor 14, spinning in a first direction, is quickly slowed to a zero or near zero velocity by being operated in a braking mode. In braking mode the spinning motor 14 acts as a generator and energy is absorbed by any or all of the motor windings 120, motor controller 18, or the battery. As the motor 14 is at or near zero velocity it will be driven by the controller 18 in a second direction. At first the motor 14 is driven the second direction at a first fast acceleration. When the controller 18 determines that the motor 14 is close to the engagement speed the motor 14 will be driven at a second slower acceleration. This is to ensure a smooth re-engagement and prevent the motor 14 from creating a shock load that can damage the transmission 16 and cause unpleasant noise and vibration. The controller 18 can determine the engagement speed by using a pre-determined value from memory or from the signal from the hub speed sensor 124.

When the rider has been coasting and not pedalling the hub shell 36 will be rotating but the motor 14 will be off and not rotating. During this time the motor controller 14 monitors the hub speed. When the rider begins to pedal and applies load to the pedals the motor controller 18 uses the measured hub speed to determine what direction the motor 14 should be operated. If the hub speed is below a predetermined first value stored in memory the hub 10 will operate in a first gear; if the speed is above a second value stored in memory, the hub 10 will operate in second gear. The first and second hub speed values can be the same value. The motor 14 starts with a first fast acceleration. When the controller 18 determines that the motor speed is close to the engagement speed the motor 14 will accelerate with a second slower acceleration. The engagement speed can be determined from the hub speed sensor 124 or other means.

The rate of acceleration of the motor 14 can be controlled by various methods. One method is to control the rate that the current changes. In this case the motor 14 would start a first rate of current change and switch to a second rate of current change when the motor 14 is close to engaging the transmission 16.

Another feature of the motor controller 18 in the current invention is a soft pedal mode. When a rider is pedalling with very low pulsed load the motor 14 could continually be switched on and off, causing excessive wear, noise, and vibration. To eliminate this undesirable condition the controller 18 will supply a minimum amount of current to the motor 14 to maintain transmission 16 engagement and smooth operation and to reduce engagement lag. Typically this amount of current supplied is about 1 amp.

Another feature of the motor controller 18 in the current invention is backward pedalling motor 14 cut-off feature. At any time if the controller 18 detects that the pedals are moved backwards, the power to the motor will be abruptly terminated. The motor controller 18 can determine the pedalling direction by the quadrature signal generated by the torque sensor 20 hall sensors, although other means could be used.

The motor controller 18 in this embodiment is located between the sprocket driver assembly 26 and the motor 14 . The motor 14 in this embodiment is a brushless type. The motor 14 has a stator portion 110 mounted (fixed) to the axle 22 and a rotor portion 42 mounted on a bearing 130 rotatable about the axle 22. The inner surface of the rotor 42 contains magnets 132. The motor controller 18 is connected to windings 120 on the stator 110 by a drive conductor 134 and configured to drive the motor 14 in a first direction and a second direction. The controller 18 uses motor position sensors 140, such as hall sensors, attached to the board reaching into the motor 14 to measure the angular position of the rotor 42. A motor thermal sensor 142 is also mounted to the motor controller 18. The controller 18 uses the motor thermal sensor 142 to monitor the temperature of the motor 14. If the monitored motor temperature exceeds a pre-determined temperature stored in memory the controller 18 can temporarily reduce the current supplied to the motor 14.

The motor controller 18 also contains a thermal sensor that monitors the temperature of the motor controller 18. If the monitored motor controller 18 temperature exceeds a pre-determined temperature stored in memory the controller 18 can temporarily reduce the current supplied to the motor 14.

A harness 144 containing power conductors 146 and optional data conductor 148 passes through a hub shell 36 bearing and is received in a slot 150 in the axle 22. The power conductors 146 and optional data conductors 148 electrically connect to

the controller 18 to provide power to the motor controller 18. A harness connector 152 is located at the external end of the harness 144 to connect to a power source 145, such as a battery, and optionally a data receiver module. The data receiver module may contain a display to show information from the motor controller 18, such as wheel speed, current gear, battery voltage, remaining battery capacity, system errors or fault conditions, trip odometer, etc. The data conductor 148 could also be used to change operation parameters of the drive hub 10, such as a power output or maximum assist speed.

Claims

1. Motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,
- a motor controller for controlling the motor,

wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on a speed parameter.

2. Motor drive hub according to claim 1,
wherein the speed parameter represents the speed of the motor or the speed of an output member of the motor drive hub or the speed of a wheel of the vehicle.

3. Motor drive hub according to claim 2,
wherein the speed parameter is provided by a speed sensor adapted to determine the speed of the motor or the speed of the output member of the motor drive hub or the speed of a wheel of the vehicle.

4. Motor drive hub according to claim 2,
wherein the speed parameter is calculated based on at least one operational parameter of the motor drive hub or the vehicle.

5. Motor drive hub according to one of the preceding claims,
further comprising a memory in which a first and second speed parameter threshold value are stored, wherein the motor controller switches the motor from the state in which it rotates in the first direction to the state in which it rotates in the second direction when the speed parameter exceeds said first speed parameter threshold value and wherein the motor controller switches the motor to rotate from the state in which it rotates in the second direction to the state in which it rotates in the first

direction when the speed parameter falls below said second speed parameter threshold value.

6. Motor drive hub according to claim 5,
wherein the first speed parameter threshold value is of the same or a higher amount than the second speed parameter threshold value.

7. Motor drive hub according to claim 5 or 6,
wherein the motor starts with a first fast acceleration and when the motor controller determines that the motor speed is close to an engagement speed the motor accelerates with a second slower acceleration.

8. Motor drive hub according to claim one of the preceding claims,
further comprising a load sensor for detecting an actual external load applied to the motor drive hub.

9. Motor drive hub according to claim 8,
wherein the motor controller controls a current supply supplied to the motor based on the external load detected by the load sensor.

10. Motor drive hub according to claim 8 or 9,
wherein the load sensor comprises a torque sensor coupled to an input driver of the motor drive hub for detecting the external torque applied to the input driver.

11. Mode for drive hub according to claim 10,
wherein the drive hub includes a drive ring which is coupled to the input driver in a torque transmitting manner by means of a spring arrangement, which spring arrangement deflects to allow a relative movement between the drive hub and the drive ring depending on the actual external torque applied to the input driver.

12. Motor drive hub according to claim 11,
wherein the input driver and the drive ring are formed by permanent magnets having at least one magnetic north pole and one south pole on a detection surface, respectively, wherein at least one magnetic sensor is associated to each of the input driver and the drive ring for detecting the actual rotational position thereof.

13. Motor drive hub according to claim 12,
wherein the at least one magnetic sensor is formed by a Hall sensor or a Reed sensor.

14. Motor drive hub according to one of the claims 9 to 13,
wherein the motor controller uses a pulse width modulation scheme to control the current supply supplied to the motor.

15. Motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,
- a load sensor for detecting an actual external load applied to the motor drive hub, and
- a motor controller for controlling the motor,

wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on the external load detected by the load sensor.

16. Motor drive hub according to one of the preceding claims,
wherein when switching between the first direction and the second direction the motor is slowed or braked in a braking mode.

17. Motor drive hub according to one of the preceding claims,
wherein the motor is operable in a braking mode in which it functions as a generator.

18. Motor drive hub according to one of the preceding claims,
wherein the motor is deactivated if the vehicle or the motor drive hub or the input driver is moved in a backward direction.

19. Motor drive hub according to one of the preceding claims, further comprising a thermal sensor for monitoring the temperature of the motor, wherein the motor is controlled depending on the actual temperature detected by the thermal sensor.

20. Motor controller for controlling a motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,

wherein the motor controller switches the motor between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on a speed parameter.

21. Motor drive hub according to claim 20, wherein the speed parameter represents the speed of the motor or the speed of an output member of the motor drive hub or the speed of a wheel of the vehicle.

22. Motor drive hub according to claim 21, wherein the speed parameter is provided by a speed sensor adapted to determine the speed of the motor or the speed of the output member of the motor drive hub or the speed of a wheel of the vehicle.

23. Motor drive hub according to claim 21, wherein the speed parameter is calculated based on at least one operational parameter of the motor drive hub or the vehicle.

24. Motor controller according to one of claims 20 to 23, further comprising a memory in which a first and second speed parameter threshold value are stored, wherein the motor controller switches the motor from the state in which it rotates in the first direction to the state in which it rotates in the second direction when the speed parameter exceeds said first speed parameter threshold

value and wherein the motor controller switches the motor to rotate from the state in which it rotates in the second direction to the state in which it rotates in the first direction when the speed parameter falls below said second speed parameter threshold value.

25. Motor controller according to claim 24,
wherein the first speed parameter threshold value is of the same or a higher amount than the second speed parameter threshold value.

26. Motor controller according to claim 24 or 25,
further comprising a load sensor for detecting an actual external load applied to the motor drive hub.

27. Motor controller according to claim 26,
wherein the motor controller controls a current supply supplied to the motor based on the external load detected by the load sensor.

28. Motor controller according to claim 26 or 27,
wherein the load sensor comprises a torque sensor coupled to an input driver of the motor drive hub for detecting the external torque applied to the input driver.

29. Motor controller according to one of the claims 26 to 28,
wherein the motor controller uses a pulse width modulation scheme to control the current supply supplied to the motor.

30. Motor controller for controlling a motor drive hub, in particular for a handlebar-steered vehicle, the motor drive hub comprising:

- a transmission assembly configured to drive the vehicle in forward direction;
- an electric motor rotatable in a first direction and in a second direction and configured to drive the transmission assembly,
- the transmission assembly configured to operate in a first operating mode when the motor is rotating in the first direction to provide at least one first drive speed in the forward direction and in a second operating mode when the motor is rotating in the second direction to provide at least one second drive speed in the forward direction,
- a load sensor for detecting an actual external load applied to the motor drive hub,

wherein the motor is switched by the motor controller between a state in which it rotates in said first direction and a state in which it rotates in said second direction depending on the external load detected by the load sensor.

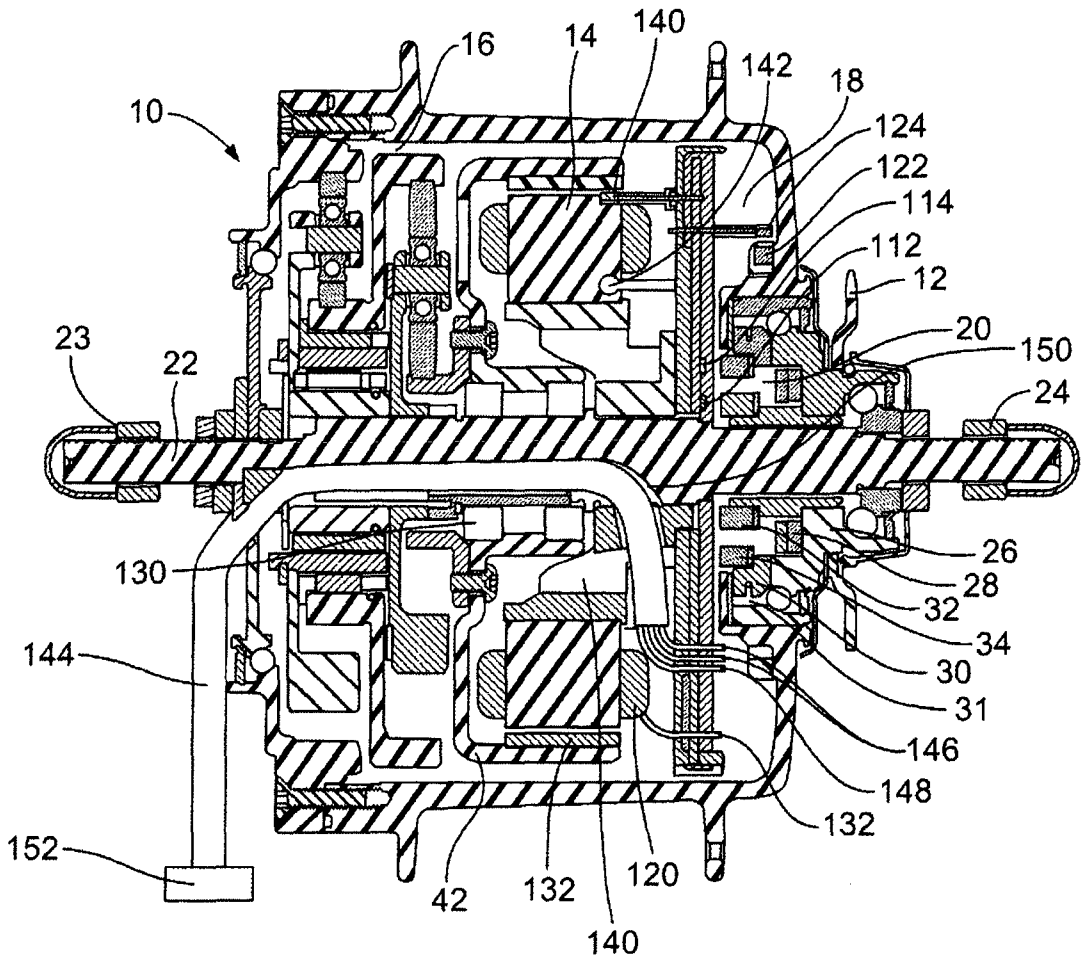

10
16
14
140
142
18
124
122
114
112
12
20
150
24
23
22
130
26
28
32
34
30
31
146
148
132
144
152
42
132
120
140

FIG. 1

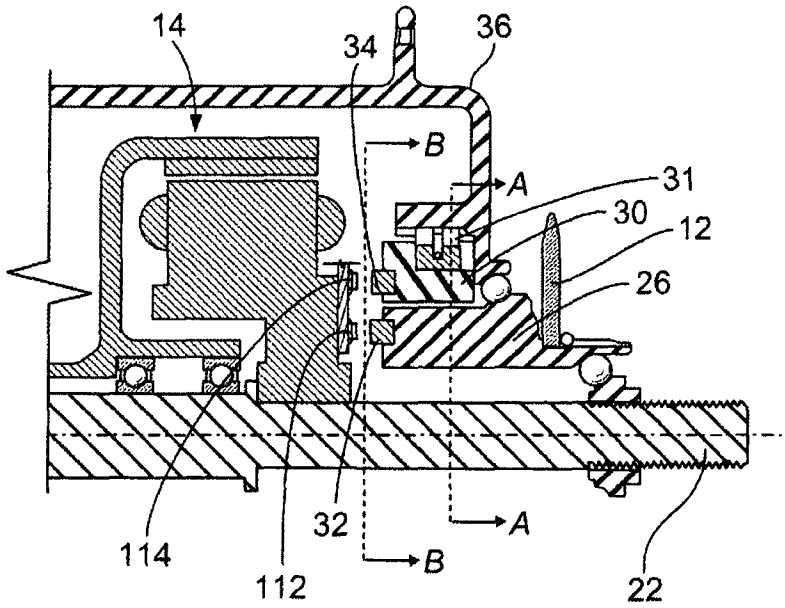
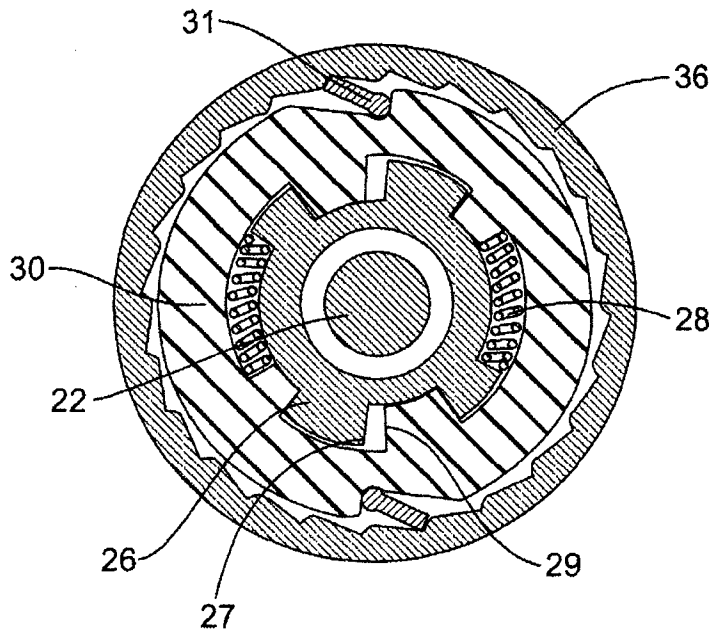
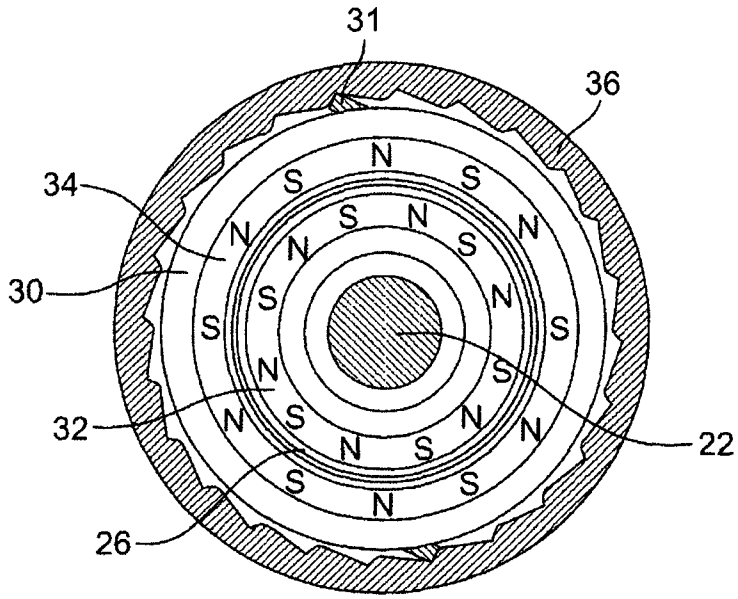


FIG. 2



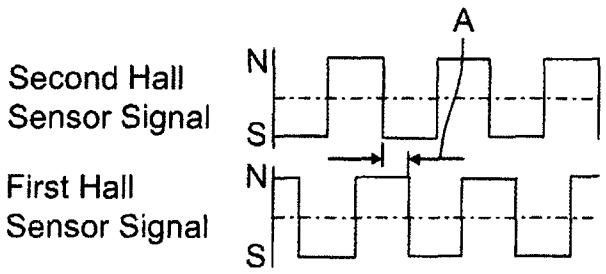
Section A-A

FIG. 3



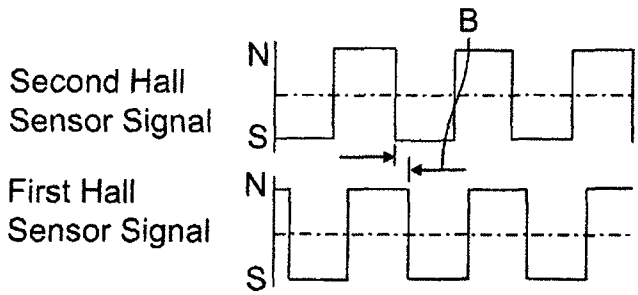
Section B-B

FIG. 4



Pedal Forward No Load

FIG. 5



Pedal Forward High Load

FIG. 6

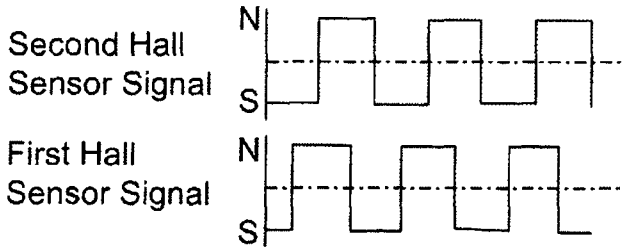

Second Hall
Sensor Signal
N
S
First Hall
Sensor Signal
N
S
Pedal Backwards

FIG. 7

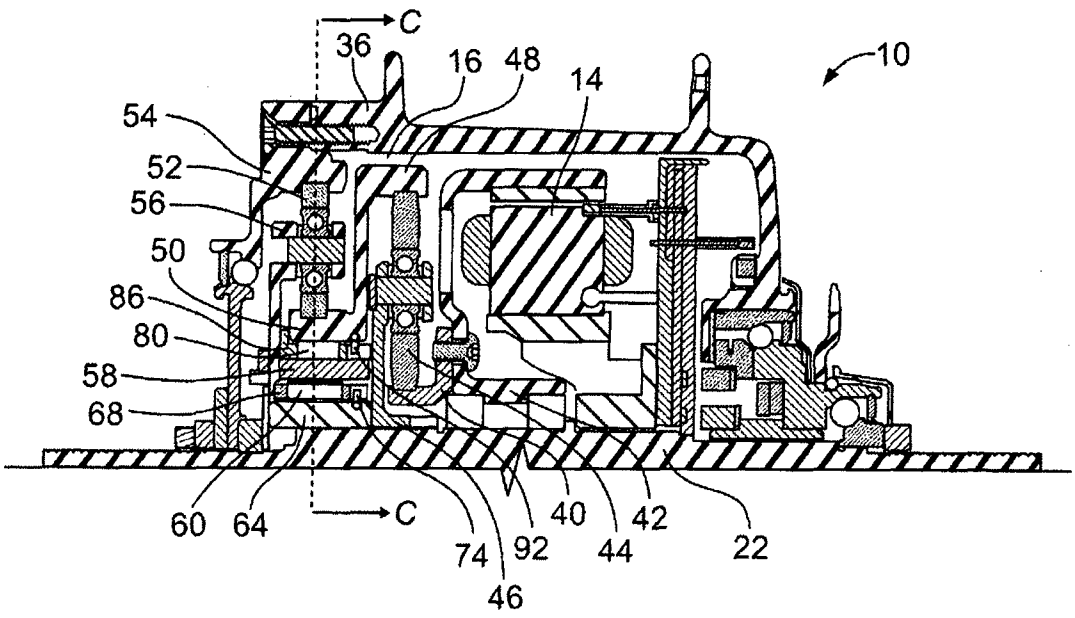
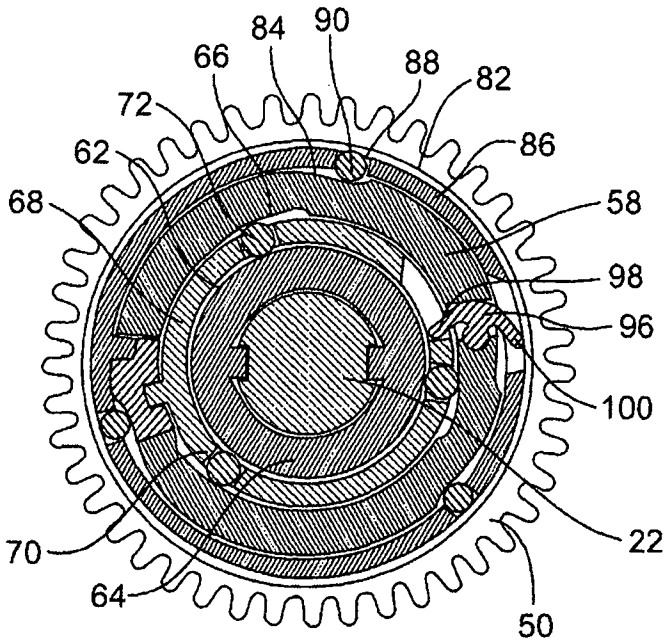
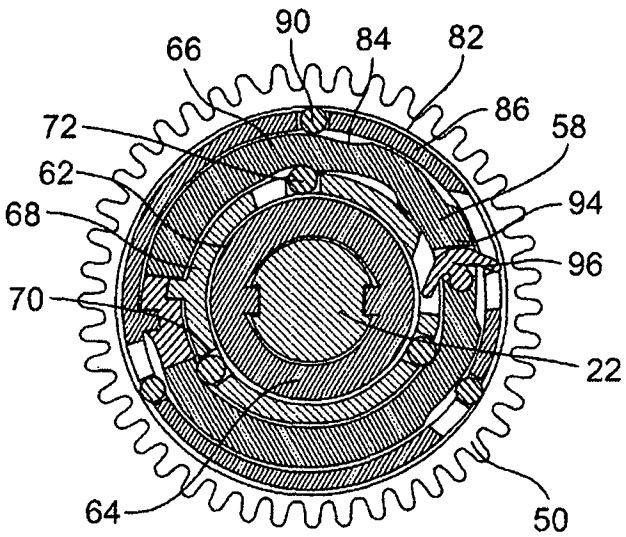

C
36
16
48
14
10
54
52
56
50
86
80
58
68
60
64
C
74
92
40
44
42
22
46

FIG. 8



Section C-C
First Gear

FIG. 9



Section C-C
Second Gear

FIG. 10

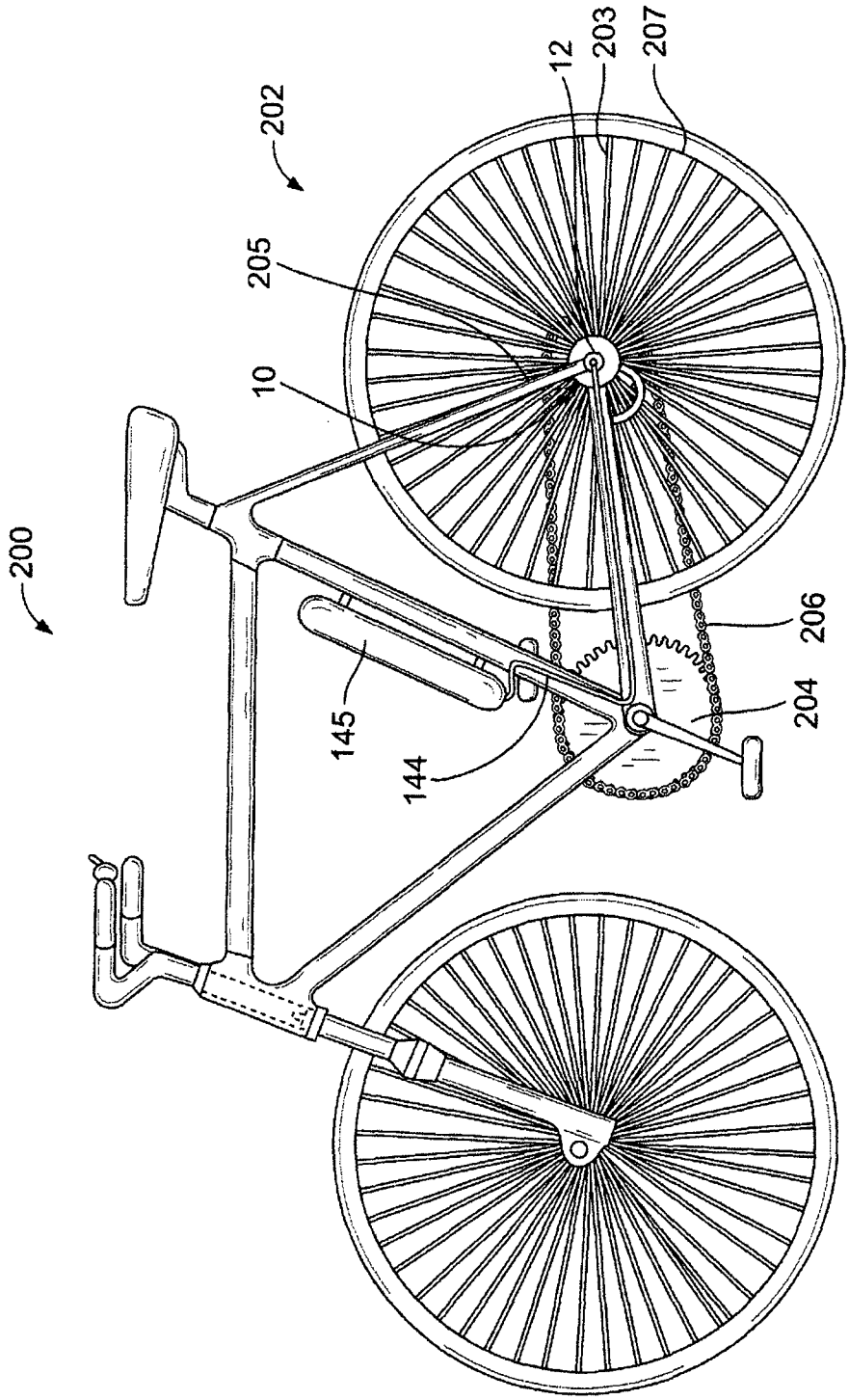


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/028686

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62M6/50 B62M6/45 B62M11/18 F16H3/00
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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/088169 A1 (MBI CO LTD [KR]; JUNG TAE-JIN [KR]; YOO HYUK [KR]) 24 July 2008 (2008-07-24)	1,20
Y	paragraph [0074] - paragraph [0078] figures 1,9	2-19, 21-30

Y	JP 2001 280464 A (AKEBONO BRAKE IND) 10 October 2001 (2001-10-10)	2-19, 21-30
A	abstract figures 1-4	1

A	EP 2 204 316 A1 (SRAM LLC [US]) 7 July 2010 (2010-07-07) paragraph [0014] - paragraph [0020] figure 1	1,15,20, 30

	-/--	

[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 document 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
13 October 2011	19/10/2011

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	Verdelho, Luís

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/028686

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/034283 A1 (TSAI MING-CHIH [TW] ET AL) 10 February 2011 (2011-02-10) paragraph [0015] - paragraph [0020] figure 1	1,15,20, 30
A	EP 1 212 236 B1 (FERRERO SPA [IT]) 4 February 2004 (2004-02-04) paragraph [0009] - paragraph [0020] figures 1-4	1-30

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/028686

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008088169 A1	24-07-2008	NONE	
JP 2001280464 A	10-10-2001	NONE	
EP 2204316 A1	07-07-2010	CN 101774418 A	14-07-2010
		US 2010170731 A1	08-07-2010
US 2011034283 A1	10-02-2011	NONE	
EP 1212236 B1	04-02-2004	AT 258868 T	15-02-2004
		AU 6997700 A	19-03-2001
		CA 2382424 A1	01-03-2001
		CN 1379721 A	13-11-2002
		DE 60008123 D1	11-03-2004
		DE 60008123 T2	15-07-2004
		DK 1212236 T3	13-04-2004
		WO 0114203 A1	01-03-2001
		EP 1212236 A1	12-06-2002
		ES 2213039 T3	16-08-2004
		HK 1047267 A1	09-07-2004
		IT T0990722 A1	26-02-2001
		JP 2003507261 A	25-02-2003
		PT 1212236 E	31-05-2004
		US 6714849 B1	30-03-2004