

REGENERATIVE BRAKE SYSTEM

BACKGROUND ART

5 The present disclosure relates to a regenerative brake system.

 Japanese Patent Application Publication No. 2014-69786 discloses a vehicle brake device including a hydraulic brake mechanism and a regenerative brake mechanism. The regenerative brake mechanism of this vehicle brake
10 device includes a motor that drives to rotate drive wheels and generates regenerative electric power from the kinetic energy of the rotating drive wheels, an inverter that supplies electric power stored in a battery to the motor and converts the regenerative electric power generated by the motor to an electric power that can be stored in the battery, and a controller that limits brake by the hydraulic
15 brake mechanism and controls the motor to suppress loss of energy which can be recovered by the regenerative braking.

 When the vehicle travels on a long downhill slope while applying the brake, the battery may become unable to receive the electric power (regenerative electric
20 power) generated by the motor by way of regenerative braking, with the result that the regenerative brake may not be fully applied. In this case, the energy generated by the regenerative braking is not recovered as electrical energy, but is converted into heat by the mechanical brake and discarded.

25 The present disclosure is directed to providing a regenerative brake system capable of improving the energy recovery efficiency which corresponds to energy recovered by regenerative braking while the vehicle travels a downhill slope.

30 SUMMARY

According to one aspect of the present disclosure, there is provided a regenerative brake system using regenerative braking that applies braking to a vehicle while recovering kinetic energy of the vehicle by operating an electric motor that causes the vehicle to travel along a travel path as a generator, the regenerative brake system including a battery mounted on the vehicle, a vehicle-side power transmitting unit that is mounted on the vehicle and transmits electric power generated by the electric motor by the regenerative braking when the vehicle travels down a slope of the travel path, a travel path-side power receiving unit that is installed in the slope and receives the electric power transmitted from the vehicle-side power transmitting unit, and a power storage device that is connected to the travel path-side power receiving unit and stores the electric power received by the travel path-side power receiving unit.

Other aspects and advantages of the disclosure will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure, together with objects and advantages thereof, may best be understood by reference to the following description of the embodiments together with the accompanying drawings in which:

FIG. 1 is a schematic configuration view illustrating a regenerative brake system according to a first embodiment of the present disclosure;

FIG. 2 is a block diagram of the regenerative brake system shown in FIG. 1;

FIG. 3 is a flowchart illustrating details of Steps of a regenerative control process executed by a regenerative control unit shown in FIG. 2;

FIG. 4 is a flowchart illustrating details of Steps of a control process executed by a controller shown in FIG. 2;

FIG. 5 is a schematic configuration view illustrating a regenerative brake system according to a second embodiment of the present disclosure; and

FIG. 6 is a block diagram of the regenerative brake system shown in FIG. 5.

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DETAILED DESCRIPTION OF THE EMBODIMENTS

Hereinafter, embodiments of the present disclosure will be described in detail with reference to the drawings. In the figures, the same or equivalent elements are denoted with the same reference numerals, and redundant description will be omitted.

FIG. 1 is a schematic configuration view illustrating a regenerative brake system according to a first embodiment of the present disclosure. FIG. 2 is a block diagram of the regenerative brake system shown in FIG. 1. A regenerative brake system 1 of the present embodiment illustrated in FIGS. 1 and 2, is applied to , for example, a travel path A in which an underpass 2 exists in a site such as an airport or a factory. In the present example, a plurality of industrial vehicles 3 such as towing tractors travels along the travel path A. The industrial vehicle 3 is, for example, a battery vehicle or a hybrid vehicle.

The regenerative brake system 1 is a system using regenerative braking in which the kinetic energy of the industrial vehicle 3 is recovered as electrical energy while applying braking to the industrial vehicle 3 when the industrial vehicle 3 travels on a long downhill slope in the underpass 2.

The regenerative brake system 1 includes a traveling unit 4 mounted on the industrial vehicle 3, a plurality of power transmitting/receiving devices 5 installed in a slope 2a of the underpass 2, and a power storage device 6 installed in the site.

The traveling unit 4 includes a battery 7, an electric motor 8, a motor driver 9, a power transmitter 10, a power receiver 11, an accelerator sensor 12, a slope detection sensor 14, and an ECU 15 (Electronic Control Unit).

5 The battery 7 serves as a power storage apparatus configured to store electric power (electricity) to be used for traveling of the industrial vehicle 3. That is, the battery 7 stores electric power to be supplied to the electric motor 8.

10 The electric motor 8 is an AC motor configured to cause the industrial vehicle 3 to travel by the electric power stored in the battery 7. The electric motor 8 drives the drive wheels 3a of the industrial vehicle 3 to rotate. The electric motor 8 also functions as a generator. Specifically, when the industrial vehicle 3 decelerates, or when the industrial vehicle 3 travels on a downhill slope, the electric motor 8 operates as a generator with the rotation of the drive wheels 3a.
15 When the electric motor 8 operates as a generator, the regenerative braking is applied to the drive wheels 3a, and electric power is generated by the electric motor 8.

20 The motor driver 9 drives the electric motor 8 and switches the supply destination of the electric power generated by the electric motor 8 by the regenerative braking. When the motor driver 9 causes the electric motor 8 to the drive wheel 3a, the motor driver 9 converts the DC power stored in the battery 7 into AC power and supplies it to the electric motor 8. When the electric motor 8 operates as a generator, the motor driver 9 converts the AC power generated by
25 the electric motor 8 into DC power and supplies it to the battery 7, or supplies the AC power generated by the electric motor 8 to the power transmitter 10. Furthermore, the motor driver 9 switches between the power transmitting operation by the power transmitter 10 and the power receiving operation by the power receiver 11.

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 The power transmitter 10 serves as a vehicle-side power transmitting unit configured to transmit the electric power generated by the electric motor 8 by way

of regenerative braking when the industrial vehicle 3 travels down the slope 2a of the underpass 2. The power transmitter 10 is, for example, an electromagnetic induction type power transmitter having a power transmitting coil. The power transmitter 10 transmits the electric power generated by the electric motor 8 by way of regenerative braking in a non-contact manner.

The power receiver 11 serves as a vehicle-side power receiving unit configured to receive the electric power transmitted from a power transmitter 21 (which will be described later) of the power transmitting/receiving device 5. The power receiver 11 is, for example, an electromagnetic induction type power receiver having a power receiving coil. The power receiver 11 receives the electric power from the power transmitter 21 in a non-contact manner.

The accelerator sensor 12 is a sensor configured to detect the operation amount of the accelerator. The slope detection sensor 14 is a sensor configured to detect whether or not the industrial vehicle 3 is traveling on the slope 2a of the underpass 2. As the slope detection sensor 14, for example, a camera, an inclination sensor, a vehicle speed sensor, an acceleration sensor, or the like may be used. The slope detection sensor 14 serves as a climbing detection unit that detects whether or not the industrial vehicle 3 is travelling up the slope 2a. As a method for detecting whether or not the industrial vehicle 3 is traveling on the slope 2a, for example, the current position of the industrial vehicle 3 may be estimated by using a self-position estimation technique such as SLAM.

The ECU 15 includes a CPU, a RAM, a ROM, an input/output interface, and the like. The ECU 15 acquires the detected values of the accelerator sensor 12, the slope detection sensor 14, and the like, executes a predetermined process, and controls the electric motor 8 and the motor driver 9. The ECU 15 includes a voltage detection unit 13, a drive control unit 16, a regenerative control unit 17, a charge control unit 18, and a vehicle information transmitting unit 19.

The voltage detection unit 13 detects the voltage value of the battery 7. The voltage detection unit 13 serves as a charge detection unit that detects the charge amount of the battery 7.

5 When the accelerator sensor 12 detects an accelerator operation (accelerator ON), the drive control unit 16 controls the electric motor 8 through the motor driver 9 so as to rotate the drive wheels 3a according to the amount of accelerator operation.

10 When the accelerator sensor 12 detects release of the accelerator operation (accelerator OFF), the regenerative control unit 17 controls the motor driver 9 so as to supply the electric power (regenerative electric power) generated by the electric motor 8 by way of the regenerative braking.

15 FIG. 3 is a flowchart illustrating details of Steps of a regenerative control process executed by the regenerative control unit 17. Referring to FIG. 3, firstly, the regenerative control unit 17 acquires the detected value of the accelerator sensor 12 (Step S101). Then, the regenerative control unit 17 determines whether or not the accelerator operation has been released, that is, whether or not
20 the accelerator is OFF, based on the detected value of the accelerator sensor 12 (Step S102). When the regenerative control unit 17 determines that the accelerator operation has not been released, the regenerative control unit 17 executes the above Step S101 again.

25 When the regenerative control unit 17 determines that the accelerator operation has been released, the regenerative control unit 17 acquires the detected value of the slope detection sensor 14 (Step S103). Then, the regenerative control unit 17 determines whether or not the industrial vehicle 3 is travelling down the slope 2a of the underpass 2, that is, whether or not the
30 industrial vehicle 3 is traveling a downhill slope based on the detected value of the slope detection sensor 14 (Step S104).

When the regenerative control unit 17 determines that the industrial vehicle 3 is travelling down the slope 2a, the regenerative control unit 17 acquires the voltage value of the battery 7 detected by the voltage detection unit 13 (Step S105). Then, the regenerative control unit 17 determines whether or not the battery 7 is in a fully charged state based on the acquired voltage value of the battery 7 (Step S106).

When the regenerative control unit 17 determines that the battery 7 is not in a fully charged state, the regenerative control unit 17 controls the motor driver 9 so as to charge the battery 7 with the regenerative electric power generated by the electric motor 8 by the regenerative braking (Step S107). Then, the regenerative control unit 17 executes the above Step S101 again.

When the regenerative control unit 17 determines that the battery 7 is in a fully charged state, the regenerative control unit 17 controls the motor driver 9 so as to supply the regenerative electric power generated by the electric motor 8 by way of the regenerative braking to the power transmitter 10 (Step S108). Then, the regenerative control unit 17 executes the above Step S101 again.

When the regenerative control unit 17 determines at Step S104 that the industrial vehicle 3 is not travelling down the slope 2a, the regenerative control unit 17 controls the motor driver 9 so as to charge the battery 7 with the regenerative electric power generated by the electric motor 8 by way of the regenerative braking (Step S107). Then, the regenerative control unit 17 executes the above Step S101 again.

Returning to FIG. 2, when the slope detection sensor 14 detects that the industrial vehicle 3 is travelling up the slope 2a of the underpass 2, the charge control unit 18 controls the motor driver 9 so that the battery 7 can be charged with the electric power received by the power receiver 11.

The vehicle information transmitting unit 19 acquires the voltage value of the battery 7 detected by the voltage detection unit 13 and the detected value of the slope detection sensor 14, and transmits them wirelessly or the like as vehicle information to a controller 23 (which will be described later) of the power transmitting/receiving device 5.

The power transmitting/receiving device 5 includes a power receiver 20, a power transmitter 21, a switching unit 22, and the controller 23.

The power receiver 20 serves as a travel path-side power receiving unit configured to receive the electric power transmitted from the power transmitter 10 of the traveling unit 4 of the industrial vehicle 3. The power receiver 20 is, for example, an electromagnetic induction type power receiver having a power receiving coil. The power receiver 20 receives the electric power from the power transmitter 10 in a non-contact manner.

The power transmitter 21 serves as a travel path-side power transmitting unit configured to transmit the electric power stored in the power storage device 6. The power transmitter 21 is, for example, an electromagnetic induction type power transmitter having a power transmitting coil. The power transmitter 21 transmits the electric power stored in the power storage device 6 in a non-contact manner.

The switching unit 22 switches between the power receiving operation by the power receiver 20 and the power transmitting operation by the power transmitter 21.

The controller 23 includes a CPU, a RAM, a ROM, an input/output interface, and the like. The controller 23 wirelessly receives and acquires vehicle information transmitted from the vehicle information transmitting unit 19 of the traveling unit 4, executes a predetermined process, and controls the switching unit 22.

FIG. 4 is a flowchart illustrating details of Steps of a control process executed by the controller 23. Referring to FIG. 4, firstly, the controller 23 acquires the vehicle information from the vehicle information transmitting unit 19 (Step S111). Then, the controller 23 determines whether or not the industrial vehicle 3 is travelling up the slope 2a of the underpass 2, that is, whether or not the industrial vehicle 3 is traveling an uphill slope based on the vehicle information (Step S112).

When the controller 23 determines that the industrial vehicle 3 is travelling up the slope 2a, the controller 23 determines whether or not the charge amount of the battery 7 of the industrial vehicle 3 is equal to or less than a specified value that is determined in advance based on the vehicle information (Step S113).

When the controller 23 determines that the charge amount of the battery 7 is equal to or less than the specified value, the controller 23 controls the switching unit 22 to transmit the electric power stored in the power storage device 6 by the power transmitter 21 (Step S114). Then, the controller 23 executes the above Step S111 again.

When the controller 23 determines at Step S112 that the industrial vehicle 3 is not travelling up the slope 2a, or the controller 23 determines at Step S113 that the charge amount of the battery 7 is not equal to or less than the specified value, the controller 23 controls the switching unit 22 so as to supply the electric power received by the power receiver 20 to the power storage device 6 (Step S115). Then, the controller 23 executes the above Step S111 again.

Returning to FIG. 2, the power storage device 6 is connected to the switching unit 22 of each of the plurality of power transmitting/receiving devices 5. The power storage device 6 stores the electric power received by the power receiver 20 of the power transmitting/receiving device 5.

The motor driver 9, the regenerative control unit 17, the charge control unit 18, the vehicle information transmitting unit 19, the switching unit 22, and the controller 23 constitute a power supply control unit that performs a control through which the electric power stored in the power storage device 6 is supplied to the battery 7 through the power transmitter 21 and the power receiver 11.

According to the above-described regenerative brake system 1, when the industrial vehicle 3 travels down the slope 2a of the underpass 2, the electric motor 8 operates as a generator with the rotation of the drive wheels 3a by releasing the accelerator operation. Consequently, the regenerative braking is applied to the industrial vehicle 3, and the battery 7 is charged with the regenerative electric power generated by the electric motor 8 by way of the regenerative braking through the motor driver 9.

At this time, when the battery 7 is fully charged, the battery 7 becomes unable to receive the regenerative electric power. Thus, the regenerative electric power is supplied to the power storage device 6 through the power transmitting/receiving device 5 installed in the slope 2a. Specifically, the regenerative electric power is transmitted to the power transmitter 10 through the motor driver 9, which is then transmitted from the power transmitter 10. Then, the regenerative electric power from the power transmitter 10 is received by the power receiver 20 of the power transmitting/receiving device 5, and stored in the power storage device 6 through the switching unit 22.

The electric power stored in the power storage device 6 is supplied to another industrial vehicle 3 travelling up the slope 2a of the underpass 2 through the power transmitting/receiving device 5. Specifically, the electric power stored in the power storage device 6 is transmitted to the power transmitter 21 through the switching unit 22 in the power transmitting/receiving device 5, which is then transmitted from the power transmitter 21. Then, the electric power from the power transmitter 21 is received by the power receiver 11 of the other industrial vehicle 3, and the battery 7 is charged through the motor driver 9.

As has been described, in the present embodiment, when the industrial vehicle 3 travels down the slope 2a, the electric motor 8 operates as a generator, so that the regenerative braking is applied to the industrial vehicle 3, and the electric power generated by the electric motor 8 by way of the regenerative braking is transmitted by the power transmitter 10. Then, the electric power from the power transmitter 10 is received by the power receiver 20 of the power transmitting/receiving device 5 and stored in the power storage device 6. The electric power stored in the power storage device 6 is supplied to another industrial vehicle 3. Therefore, of the energy generated by the regenerative braking, a part of the energy which is to be discarded as heat is recovered as electric power and used for other industrial vehicles 3. Accordingly, the energy recovery efficiency which corresponds to energy is recovered by regenerative braking while the industrial vehicle 3 travels the downhill slope is improved. As a result, the operational time of the industrial vehicle 3 can be improved. Additionally, the cost of electric power for charging the battery 7 of the industrial vehicle 3 can be suppressed.

In the present embodiment, the electric power stored in the power storage device 6 is supplied to the battery 7 through the power transmitter 21 of the power transmitting/receiving device 5 and the power receiver 11 of the industrial vehicle 3. Therefore, the energy recovery efficiency by the regenerative braking is reliably improved.

In the present embodiment, when the industrial vehicle 3 is travelling up the slope 2a, the electric power stored in the power storage device 6 is supplied to the battery 7 through the power transmitter 21 and the power receiver 11. When the industrial vehicle 3 travels on the uphill slope, the electric motor 8 requires a larger amount of electric power than when the industrial vehicle 3 travels on a flat travel path. Therefore, when the industrial vehicle 3 travels the uphill slope, the electric power generated by the regenerative braking can be efficiently utilized by supplying the electric power stored in the power storage device 6 to the battery 7 of the industrial vehicle 3.

In the present embodiment, when the charge amount of the battery 7 is equal to or less than the specified value, the battery 7 is charged with electric power stored in the power storage device 6 through the power transmitter 21 and the power receiver 11. Thus, the electric power stored in the power storage device 6 is supplied to the battery 7 having a small amount of charge. Therefore, the electric power generated by the regenerative braking can be utilized more efficiently.

FIG. 5 is a schematic configuration view illustrating a regenerative brake system according to a second embodiment of the present disclosure. FIG. 6 is a block diagram of the regenerative brake system shown in FIG. 5. In FIGS. 5 and 6, a regenerative brake system 1A of the present embodiment includes a traveling unit 4A mounted on the industrial vehicle 3, a plurality of power receiving devices 30 installed on the slope 2a of the underpass 2, the power storage device 6, and a charging stand 31.

The traveling unit 4A includes a battery 7, an electric motor 8, a motor driver 9, a power transmitter 10, an accelerator sensor 12, a slope detection sensor 14, and an ECU 15A. The traveling unit 4A does not include the power receiver 11 as described in the first embodiment.

The ECU 15A includes a voltage detection unit 13, a drive control unit 16, and a regenerative control unit 17. The ECU 15A does not include the charge control unit 18 and the vehicle information transmitting unit 19 as described in the first embodiment.

The power receiving device 30 is connected to the power storage device 6. The power receiving device 30 includes a power receiver 20. The power receiving device 30 does not include the power transmitter 21 and the switching unit 22 as described in the first embodiment. Therefore, the regenerative electric power generated by the regenerative braking in the industrial vehicle 3 is supplied to the power storage device 6 through the power receiving device 30. However,

the electric power stored in the power storage device 6 is not supplied to the battery 7 of the industrial vehicle 3 through the power receiving device 30. The power receiving device 30 may include a controller.

5 The charging stand 31 serves as a charging station installed on the travel path A on which the industrial vehicle 3 travels. The charging stand 31 is connected to the power storage device 6. The charging stand 31 has a charger 32 that charges the battery 7 of the industrial vehicle 3 using the electric power stored in the power storage device 6, and a charge button 33 for instructing the
10 charging of the battery 7 by the charger 32.

 In charging the battery 7 of the industrial vehicle 3 at the charging stand 31, the charge button 33 is turned ON while the battery 7 and the charger 32 are connected through a battery cable. Then, the electric power stored in the power
15 storage device 6 is supplied to the battery 7 through the charger 32, thus charging the battery 7.

 In this way, in the present embodiment, the electric power stored in the power storage device 6 is supplied to the battery 7 of the industrial vehicle 3
20 through the charging stand 31 to charge the battery 7. Since the power receiver 11 and the power transmitter 21 in the first embodiment are not necessary by installing the charging stand 31, the regenerative brake system 1A can be simplified.

25 The present disclosure is not limited to the above embodiments. For example, the regenerative brake system 1 of the first embodiment includes the power transmitting/receiving device 5 having the power receiver 20, the power transmitter 21, the switching unit 22, and the controller 23, but it is not particularly limited to such configuration. The regenerative brake system 1 may include a
30 power receiving device having a power receiving coil, a controller for the power receiving device, a power transmitting device having a power transmitting coil, and a controller for the power transmitting device.

Furthermore, the electric power stored in the power storage device 6 is supplied to the battery 7 of the industrial vehicle 3 in the above first embodiment when the industrial vehicle 3 travels an uphill, but it is not particularly limited thereto, The electric power stored in the power storage device 6 may be supplied to the industrial vehicle 3 when the industrial vehicle 3 travels on the flat travel path. In this case, the power transmitting/receiving device 5 is installed in the flat travel path.

Although the power transmitter 10 of the industrial vehicle 3 transmits the electric power generated by the regenerative braking in a non-contact manner, and the power receiver 20 of the power transmitting/receiving device 5 receives the electric power from the power transmitter 10 in a non-contact manner in the above embodiments, the power transmitter 10 and the power receiver 20 are not particularly limited to such a non-contact type, but may be a contact type. The contact type power transmitter 10 may be provided by, for example, a metal roller attached to the lower part of the industrial vehicle 3. The contact type power receiver 20 may be provided by, for example, a metal rail installed on the travel path A and in contact with the metal roller.

In the above embodiments, the slope detection sensor 14 that detects whether or not the industrial vehicle 3 is traveling on the slope 2a of the underpass 2 is mounted on the industrial vehicle 3, but it is not particularly limited thereto, and the slope detection sensor 14 may be installed on the slope 2a. The slope detection sensor used in this case includes, for example, a contact sensor, an infrared sensor, or the like.

In the above embodiments, the regenerative brake system 1 is applied to the industrial vehicle 3 in which the kinetic energy of the industrial vehicle 3 is recovered as electrical energy by the regenerative braking when the industrial vehicle 3 travels the downhill slope, but the present disclosure is also applicable to vehicles other than the industrial vehicle 3. For example, the present

disclosure is applicable to a vehicle such as a truck in which the kinetic energy of the vehicle is recovered when the industrial vehicle 3 travels the downhill slope.

What is claimed is:

1. A regenerative brake system using regenerative braking that applies braking to a vehicle while recovering kinetic energy of the vehicle by operating an electric motor that causes the vehicle to travel along a travel path as a generator,
5 the regenerative brake system comprising:
 - a battery mounted on the vehicle;
 - a vehicle-side power transmitting unit that is mounted on the vehicle and transmits electric power generated by the electric motor by the regenerative
10 braking when the vehicle travels down a slope of the travel path;
 - a travel path-side power receiving unit that is installed in the slope and receives the electric power transmitted from the vehicle-side power transmitting unit; and
 - a power storage device that is connected to the travel path-side power
15 receiving unit and stores the electric power received by the travel path-side power receiving unit.
2. The regenerative brake system according to claim 1, further comprising:
 - a travel path-side power transmitting unit that is installed in the travel path, is
20 connected to the power storage device, and transmits the electric power stored in the power storage device;
 - a vehicle-side power receiving unit that is mounted on the vehicle and receives the electric power transmitted from the travel path-side power transmitting unit; and
 - 25 a power supply control unit that performs a control through which the electric power stored in the power storage device is supplied to the battery through the travel path-side power transmitting unit and the vehicle-side power receiving unit.
- 30 3. The regenerative brake system according to claim 2, further comprising a climbing detection unit that detects whether or not the vehicle is travelling up the slope, wherein

the travel path-side power transmitting unit is installed in the slope, and
when the climbing detection unit detects that the vehicle is travelling up
the slope, the power supply control unit performs the control through which the
electric power stored in the power storage device is supplied to the battery through
5 the travel path-side power transmitting unit and the vehicle-side power receiving
unit.

4. The regenerative brake according to claim 2 or 3, further comprising a
charge detection unit that detects a charge amount of the battery, wherein
10 when the charge amount of the battery detected by the charge detection
unit is equal to or less than a specified value, the power supply control unit
performs the control through which the supply of the electric power stored in the
power storage device is supplied to the battery through the travel path-side power
transmitting unit and the vehicle-side power receiving unit.

15 5. The regenerative brake system according to any one of claims 1 to 4,
further comprising a charging station that is installed on the travel path and
connected to the power storage device to charge the battery using the electric
power stored in the power storage device.

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