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Braking control device

Abstract

The present disclosure is, for example, a braking control device for application in a vehicle. The braking control device includes: a hydraulic brake device that presses a braking member using hydraulic pressure toward a braked member that rotates integrally with a wheel to generate hydraulic braking force; and an electric brake device that presses the braking member using driving force of a motor toward the braked member to generate electric braking force. The braking control device adjusts the hydraulic braking force so that a vehicle speed falls within a target vehicle speed range while the vehicle is traveling on a downhill road, and replaces the hydraulic braking force with the electric braking force when at least one of the vehicle speed and the hydraulic pressure is stabilized.

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Background/Summary

TECHNICAL FIELD
(1) The present disclosure relates to a braking control device.
BACKGROUND ART

(2) In recent years, electric parking brakes have been widely adopted for various vehicles such as passenger cars. An electric parking brake is also referred to as an electric parking brake (EPB) or an electric brake device. A braking control device that controls the EPB generates electric braking force by driving a wheel brake mechanism using a motor, for example.
(3) In a case where a vehicle travels on a downhill road (downward slope), there is a possibility that wheel slip or locking will occur when normal braking control is performed. As a countermeasure, there is downhill assist control (DAC) braking control. In DAC, braking force is controlled so as to avoid wheel slip or locking, and the vehicle speed is maintained within a target vehicle speed range. As a result, the driver can concentrate on steering operation with a sense of security.
(4) Generally, when comparing hydraulic braking force to electric braking force, hydraulic braking force is superior in responsiveness. Therefore, in the case of a vehicle including a wheel brake mechanism capable of generating both hydraulic braking force and electric braking force, DAC uses hydraulic braking force.
CITATIONS LIST
Patent Literature
(5) Patent Literature 1: JP 2008-273387 A
SUMMARY
Technical Problems
(6) However, in the prior art described above, since it is necessary to control braking force according to a traveling state including the speed and acceleration of the vehicle during DAC, it is necessary to continuously actuate the motor of a hydraulic brake device. As such, the hydraulic brake device may overheat due to continuous actuation for an extended period.
(7) Therefore, one of the problems of the present disclosure is to provide a braking control device capable of suppressing overheating of the hydraulic brake device during DAC in a vehicle equipped with both a hydraulic brake device and an electric brake device.
Solutions to Problems
(8) The present disclosure is, for example, a braking control device for application in a vehicle. The braking control device includes: a hydraulic brake device that presses a braking member using hydraulic pressure toward a braked member that rotates integrally with a wheel to generate hydraulic braking force; and an electric brake device that presses the braking member using driving force of a motor toward the braked member to generate electric braking force. The braking control device adjusts the hydraulic braking force by controlling the hydraulic brake device so that a vehicle speed falls within a target vehicle speed range while the vehicle is traveling on a downhill road. When at least one of the vehicle speed and the hydraulic pressure is stabilized, the braking control device controls the hydraulic brake device and the electric brake device to replace the hydraulic braking force with the electric braking force.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a schematic diagram illustrating an overall outline of a vehicle brake device of an embodiment.
(2) FIG. **2** is a schematic cross-sectional view of a rear wheel brake mechanism provided in the vehicle brake device of the embodiment.
(3) FIG. **3** is a diagram schematically illustrating a state of a vehicle traveling on a downhill road.
(4) FIGS. **4**A to **4**C are graphs schematically illustrating a state of temporal change in each piece of information during DAC in the embodiment.
(5) FIGS. **5**A to **5**C are graphs schematically illustrating the state of temporal change in each piece of information in a case where braking force is increased during DAC in the embodiment.

(6) FIGS. **6**A to **6**C are graphs schematically illustrating the state of temporal change in each piece of information in a case where braking force is reduced during DAC in the embodiment.
(7) FIG. **7** is a flowchart depicting processing by a braking control device of the embodiment.
DESCRIPTION OF EMBODIMENT
(8) The following discloses an exemplary embodiment of the present disclosure. A configuration of the embodiment described below, and actions and results (effects) brought about by the configuration are examples. The present disclosure can also be realized by configurations other than that disclosed in the following embodiment. Furthermore, according to the present disclosure, at least one of the various effects (including derivative effects) obtained by the following configuration can be obtained.
(9) In the embodiment, a vehicle brake device in which a rear wheel EPB disc brake is applied is described as an example. FIG. **1** is a schematic diagram illustrating an overall outline of the vehicle brake device of the embodiment. FIG. **2** is a schematic cross-sectional view of a rear wheel brake mechanism provided in the vehicle brake device of the embodiment. The following description makes reference to these drawings.
(10) As illustrated in FIG. **1**, the vehicle brake device of the embodiment includes a hydraulic brake device with a service brake **1**, and an EPB **2** (electric brake device).
(11) The service brake **1** is a hydraulic brake mechanism (hydraulic brake device) that generates service braking force by pressing a braking member (brake pad **11** in FIG. **2**) using hydraulic pressure toward a braked member (brake disc **12** in FIG. **2**) that rotates integrally with a wheel based on depression of a brake pedal **3** by a driver. Specifically, the service brake **1** boosts depression force corresponding to the depression of the brake pedal **3** by the driver through a booster device **4**, and then generates brake hydraulic pressure corresponding to the boosted depression force in a master cylinder (M/C) **5**. The brake hydraulic pressure is then transmitted to a wheel cylinder (W/C) **6** provided in a wheel brake mechanism of each wheel to generate service braking force. An electronic stability control (ESC)-ACT **7** for brake hydraulic pressure control is provided between the M/C **5** and the W/C **6**. The ESC-ACT **7** adjusts the service braking force generated by the service brake **1**. The ESC-ACT **7** performs various control including anti-skid control for improving vehicle safety. In addition, the ESC-ACT **7** can generate hydraulic braking force according to a command from an ESC-ECU **8** or an EPB-ECU **9** during DAC or the like, even without the driver depressing the brake pedal **3**.
(12) The various controls using the ESC-ACT **7** are performed due to instructions from the ESC-ECU **8** (braking control device) or the EPB-ECU **9** that control hydraulic braking force. For example, the ESC-ECU **8** outputs a control current for controlling various unillustrated control valves and an unillustrated pump driving motor included in the ESC-ACT **7**, thereby controlling a hydraulic pressure circuit included in the ESC-ACT **7** and controlling W/C pressure transmitted to the W/C **6**. As a result, wheel slip is avoided, and vehicle safety is improved.
(13) For example, the ESC-ACT **7** includes, for each wheel, elements such as a pressure increase control valve that controls application of the brake hydraulic pressure generated in the M/C **5** or the brake hydraulic pressure generated by pump drive to the W/C **6** and a pressure decrease control valve that reduces W/C pressure by supplying brake fluid in each W/C **6** to a reservoir, and is configured to be capable of controlling increase, hold, and reduction of the W/C pressure. In addition, the ESC-ACT **7** can realize an automatic pressurization function of the hydraulic brake device, and can automatically pressurize the W/C **6** based on control of the pump drive and various control valves even in a state where there is no brake operation.
(14) The EPB **2** generates an electric braking force by driving the wheel brake mechanism using a motor **10**. The EPB **2** includes an EPB-ECU **9** (braking control device) that controls driving of the motor **10**. For example, the EPB **2** presses the braking member (brake pad **11** in FIG. **2**) toward the braked member (brake disc **12** in FIG. **2**) by driving the motor **10** and generates electric braking force so that the vehicle does not move unintentionally when parked. The EPB-ECU **9** and the

ESC-ECU **8** perform controller area network (CAN) communication, for example. Furthermore, the EPB-ECU **9** and the ESC-ECU **8** may be configured separately or integrally.
(15) A wheel brake mechanism is a mechanical structure that generates braking force in the vehicle brake device of the present embodiment. A front wheel brake mechanism has a structure which generates hydraulic braking force through actuation of the hydraulic brake device. By contrast, a rear wheel brake mechanism has a common use structure that generates braking force for both actuation of the hydraulic brake device and operation of the EPB **2**. The front wheel brake mechanism does not have a mechanism that generates electric braking force based on the operation of the EPB **2**. Since this is a wheel brake mechanism that has been generally used heretofore, description thereof is omitted here, and the rear wheel brake mechanism is described below.
(16) In the rear wheel brake mechanism, the brake pad **11** illustrated in FIG. **2** which is a friction material is pressed not only when the hydraulic brake device is actuated but also when the EPB **2** is actuated, and the brake disc **12** (12 RL, 12 RR, 12 FR, and 12 FL) which is a friction target material is pinched by the brake pad **11**, thereby generating frictional force, that is, braking force, between the brake pad **11** and the brake disc **12**.
(17) In a caliper **13** illustrated in FIG. **1**, the wheel brake mechanism rotates a spur gear **15** included in a drive shaft **10***a* of the motor **10** by driving the motor **10** to press the brake pad **11** as illustrated in FIG. **2**. The motor **10** is directly fixed to a body **14** of the W/C **6**. The rotational force (output) of the motor **10** is then transmitted to a spur gear **16** meshed with the spur gear **15** to move the brake pad **11**. From this, electric braking force is generated by the EPB **2**.
(18) In addition to the W/C **6** and the brake pad **11**, a part of an edge surface of the brake disc **12** is accommodated in the caliper **13** so as to be pinched by the brake pad **11**. The W/C **6** introduces brake hydraulic pressure into a hollow portion **14***a* of the cylindrical body **14** through a passage **14***b*, thereby generating W/C pressure in the hollow portion **14***a* which is a brake fluid storage chamber. Elements such as a rotating shaft **17**, a propulsion shaft **18**, and a piston **19** are provided in the hollow portion **14***a*.
(19) One end of the rotating shaft **17** is connected to the spur gear **16** through an insertion hole **14***c* formed in the body **14**. The rotating shaft **17** rotates along with the rotation of the spur gear **16**. A male screw groove **17***a* is formed in an outer peripheral surface of the rotating shaft **17** at an end portion of the rotating shaft **17** opposite to the end portion connected to the spur gear **16**. By contrast, the other end of the rotating shaft **17** is pivotally supported by being inserted into the insertion hole **14***c*. Specifically, the insertion hole **14***c* is provided with an O-ring **20** and a bearing **21**. The O-ring **20** prevents the brake fluid from leaking from a gap between the rotating shaft **17** and the inner wall surface of the insertion hole **14***c*. The bearing **21** axially supports the other end of the rotating shaft **17**.
(20) The propulsion shaft **18** is formed of a nut made of a hollow cylindrical member, and has an inner wall surface provided with a female screw groove **18***a* to be meshed with the male screw groove **17***a* of the rotating shaft **17**. The propulsion shaft **18** is formed in a columnar shape or a polygonal columnar shape provided with a key for preventing rotation for example, and thus has a structure which cannot be rotated about the rotation center of the rotating shaft **17** even when the rotating shaft **17** rotates. Therefore, when the rotating shaft **17** is rotated, the rotational force of the rotating shaft **17** is converted into a force for moving the propulsion shaft **18** in the axial direction of the rotating shaft **17** through the engagement between the male screw groove **17***a* and the female screw groove **18***a*. When the driving of the motor **10** is stopped, the propulsion shaft **18** is stopped at the same position by frictional force due to the meshing between the male screw groove **17***a* and the female screw groove **18***a*. When the driving of the motor **10** is stopped upon reaching a target electric braking force, the propulsion shaft **18** is held at that position, and a desired electric braking force can be held to achieve self-lock (hereinafter, simply referred to as “lock”).
(21) The piston **19** is disposed so as to surround the outer periphery of the propulsion shaft **18**, is formed of a bottomed cylindrical member or polygonal cylindrical member, and is disposed so that

an outer peripheral surface thereof is in contact with an inner wall surface of the hollow portion **14***a* formed in the body **14**. A seal member **22** is provided on the inner wall surface of the body **14** so as not to cause brake fluid leakage between the outer peripheral surface of the piston **19** and the inner wall surface of the body **14**, and a structure capable of applying W/C pressure to the end surface of the piston **19** is adopted. The seal member **22** is used to generate a reaction force to pull the piston **19** back at the time of release control after lock control. Basically, since the seal member **22** is provided, even if the brake pad **11** and the piston **19** are pushed by the inclined brake disc **12** within a range not exceeding an elastic deformation amount of the seal member **22** while turning, they can be pushed back to the brake disc **12** side so that the brake disc **12** and the brake pad **11** are held with a predetermined clearance (clearance C**2** in FIG. **2**) therebetween.
(22) In a case where the propulsion shaft **18** is provided with a key for preventing rotation so as not to rotate about the rotation center of the rotating shaft **17** even when the rotating shaft **17** rotates, the piston **19** is provided with a key groove in which the key is slid. In a case where the propulsion shaft **18** is formed in a polygonal columnar shape, the piston **19** is formed in a polygonal cylindrical shape corresponding to the shape of the propulsion shaft **18**.
(23) The brake pad **11** is disposed at a distal end of the piston **19**, and the brake pad **11** is moved in a horizontal direction in the drawing along with the movement of the piston **19**. Specifically, the piston **19** is configured to be movable leftward in the drawing along with the movement of the propulsion shaft **18**, and to be movable leftward in the drawing independently of the propulsion shaft **18** due to application of W/C pressure to an end portion of the piston **19** (an end portion opposite to the end portion where the brake pad **11** is disposed). When the propulsion shaft **18** is at a release position (a state before the motor **10** is rotated), which is a standby position during normal release, and the brake hydraulic pressure in the hollow portion **14***a* is not applied (W/C pressure=0), the piston **19** is moved rightward in the drawing due to elastic force of the seal member **22** described later, and the brake pad **11** is separated from the brake disc **12**.
(24) When the motor **10** is rotated and the propulsion shaft **18** is moved from its initial position leftward in the drawing, the movement of the piston **19** rightward in the drawing is restricted by the moved propulsion shaft **18** even if the W/C pressure becomes 0, and the brake pad **11** is held at that place. A clearance C**1** in FIG. **2** indicates a distance between the distal end of the propulsion shaft **18** and the piston **19**. After release completion of the EPB **2**, the propulsion shaft **18** is fixed in position with respect to the body **14**.
(25) In the wheel brake mechanism configured as above, when the hydraulic brake device is actuated, the piston **19** is moved leftward in the drawing based on the W/C pressure generated by the actuation of the hydraulic brake device, so that the brake pad **11** is pressed against the brake disc **12** to generate hydraulic braking force. When the EPB **2** is operated, the spur gear **15** is rotated by driving the motor **10**, and the spur gear **16** and the rotating shaft **17** are rotated accordingly. Therefore, the propulsion shaft **18** is moved to the side of the brake disc **12** (leftward in the drawing) based on the meshing between the male screw groove **17***a* and the female screw groove **18***a*. Along with this, the distal end of the propulsion shaft **18** then comes into contact with the piston **19** to press the piston **19**, and the piston **19** is also moved in the same direction so that the brake pad **11** is pressed against the brake disc **12** to generate electric braking force. As such, a common use wheel brake mechanism can be provided which generates braking force for both actuation of the hydraulic brake device and operation of the EPB **2**.
(26) The vehicle brake device of the embodiment is configured so that a current detection value (also simply referred to below as a “current value”) can be confirmed by a current sensor (not illustrated) that detects the current of the motor **10** to confirm a generation state of electric braking force by the EPB **2** and this current detection value can be recognized.
(27) An anteroposterior G sensor **25** detects G (acceleration) in an anteroposterior direction (traveling direction) of the vehicle and transmits a detection signal to the EPB-ECU **9**.
(28) An M/C pressure sensor **26** detects M/C pressure in the M/C **5** and transmits a detection signal

to the EPB-ECU **9**.

(29) A wheel speed sensor **29** detects the rotation speed of each wheel and transmits a detection signal to the EPB-ECU **9**. Although one wheel speed sensor **29** is actually provided for each wheel, detailed illustration and description are omitted here.

(30) The EPB-ECU **9** is composed of a known microcomputer including elements such as a central processing unit (CPU), read-only memory (ROM), random-access memory (RAM), an input/output (I/O), and performs parking brake control by controlling the rotation of the motor **10** according to a program stored in the ROM or the like.

(31) The EPB-ECU **9** receives, for example, a signal corresponding to an operation state of an operation switch (SW) **23** provided in an instrument panel (not illustrated) in the vehicle interior, and drives the motor **10** according to the operation state of the operation SW **23**. Furthermore, the EPB-ECU **9** performs lock control, release control, and the like based on the current detection value of the motor **10**, and recognizes based on the control state that lock control is being performed or that the wheel is in a locked state due to lock control, and that release control is being performed or that the wheel is in a released state (EPB release state) due to release control. The EPB-ECU **9** then outputs a signal for performing various displays to a display lamp **24** provided in the instrument panel.

(32) The vehicle brake device configured as above basically performs an action of generating braking force in the vehicle by generating service braking force using the service brake **1** while the vehicle is traveling. In addition, when the vehicle is stopped by the service brake **1**, the driver presses the operation SW **23** to actuate the EPB **2** to generate electric braking force, thereby performing an action of maintaining a stopped state and releasing the electric braking force thereafter. That is, when the driver operates the brake pedal **3** while the vehicle is traveling, brake hydraulic pressure generated in the M/C **5** is transmitted to the W/C **6** to generate service braking force as an action of the service brake **1**. In addition, the piston **19** is moved by driving the motor **10** and the brake pad **11** is pressed against the brake disc **12** to generate electric braking force to bring the wheels into a locked state, and the brake pad **11** is separated from the brake disc **12** to release the electric braking force to bring the wheels into a released state as an action of the EPB **2**.

(33) Specifically, electric braking force is generated and released through lock and release control. In lock control, the EPB **2** is actuated by rotating the motor **10** forward and the rotation of the motor **10** is stopped at a position where a desired electric braking force can be generated in the EPB **2**, and this state is maintained. From this, a desired electric braking force is generated. In release control, the EPB **2** is actuated by rotating the motor **10** in reverse, and the electric braking force generated in the EPB **2** is released.

(34) Even when the vehicle is traveling, the EPB **2** can be used in times such as an emergency, during automatic driving, or when the hydraulic brake device fails. In the present embodiment, overheating of the hydraulic brake device is also suppressed by using not only the hydraulic brake device but also the EPB **2** during DAC.

(35) Here, DAC is described with reference to FIG. **3**. FIG. **3** is a diagram schematically illustrating a state of the vehicle traveling on a downhill road. As described above, when the vehicle is traveling on a downhill road, DAC controls braking force so as to avoid slip and locking of the wheels and maintains vehicle speed within a target vehicle speed range. From this, the driver can concentrate on steering operation.

(36) In the prior art, it is necessary to adjust the braking force during DAC according to the traveling state including the speed and acceleration of the vehicle. That is, the motor of the hydraulic brake device is continuously actuated. As such, the hydraulic brake device may overheat due to continuous actuation for an extended period.

(37) The following describes a technique by which overheating of the hydraulic brake device during DAC can be suppressed in a vehicle equipped with both a hydraulic brake device and an electric brake device.

(38) When the vehicle is traveling on a downhill road during DAC, the ESC-ECU **8** controls the ESC-ACT **7** to adjust hydraulic braking force so that the vehicle speed falls within the target vehicle speed range (refer to FIG. **1**). Then, when at least one of the vehicle speed and the hydraulic pressure is stabilized, the EPB-ECU **9** controls the ESC-ACT **7** and the EPB **2** (electric brake device) to replace the hydraulic braking force with electric braking force.
(39) When, after the hydraulic braking force is replaced with the electric braking force, the gradient of the downhill road on which the vehicle is traveling increases and the vehicle speed exceeds the target vehicle speed range (condition **1**), or/and when the vehicle acceleration exceeds a first predetermined value (condition **2**), the ESC-ECU **8** controls the ESC-ACT **7** to adjust the hydraulic braking force so that the vehicle speed falls within the target vehicle speed range when the vehicle speed exceeds the target vehicle speed range, and so that the vehicle acceleration becomes equal to or smaller than the first predetermined value when the vehicle acceleration exceeds the first predetermined value. Note that in the following examples of FIGS. **4**A-**4**C, **5**A-**5**C, **6**A-**6**C and **7**, only condition **1** out of conditions **1** and **2** is adopted in order to simplify the description, but condition **2** may be used.
(40) When at least one of the vehicle speed and the hydraulic pressure is stabilized (condition **3**) or/and the absolute value of the vehicle deceleration becomes equal to or smaller than a second predetermined value (condition **4**), the EPB-ECU **9** controls the ESC-ACT **7** and the EPB **2** to replace the hydraulic braking force with electric braking force. Note that in the following examples of FIGS. **4**A-**4**C, **5**A-**5**C, **6**A-**6**C and **7**, only condition **3** out of conditions **3** and **4** is adopted in order to simplify the description, but condition **4** may be used.
(41) When the gradient of the downhill road on which the vehicle is traveling decreases and the vehicle speed falls below the target vehicle speed range after the hydraulic braking force is replaced with the electric braking force, the EPB-ECU **9** controls the EPB **2** to reduce the electric braking force so that the vehicle speed falls within the target vehicle speed range. This is described below in detail with reference to FIGS. **4**A-**4**C, **5**A-**5**C, **6**A-**6**C and **7**.
(42) FIGS. **4**A to **4**C are graphs schematically illustrating a state of temporal change in each piece of information during DAC in the embodiment. In the graph of FIGS. **4**A to **4**C, the horizontal axis represents time. The vertical axis in FIG. **4**A represents vehicle speed (kph: kilometers per hour). The vertical axis in FIG. **4**A represents the hydraulic pressure (MPa) in the hydraulic brake device generated by an instruction from the ESC-ECU **8**. The vertical axis in FIG. **4**C represents the stroke amount (movement amount of the propulsion shaft **18** (FIG. **2**)) of the EPB **2** acting according to an instruction from the EPB-ECU **9**.
(43) At time t**1**, the vehicle starts traveling on a downhill road. Then, at time t**2**, the vehicle speed reaches the lower limit value of the target vehicle speed range, and hydraulic braking force is generated. Thereafter, after the hydraulic braking force increases, at least one of the vehicle speed and the hydraulic pressure is stabilized from time t**3** to time t**4**, and the EPB **2** starts to actuate at time t**4**. Then, at time t**5**, the clearance C**1** (FIG. **2**) of the EPB **2** becomes 0. Thereafter, when the hydraulic braking force is set to 0 at time t**6**, the hydraulic braking force is replaced with electric braking force. That is, since the clearance C**1** (FIG. **2**) of the EPB **2** is 0, electric braking force equivalent to the hydraulic braking force is generated even if the hydraulic pressure becomes 0.
(44) Thereafter, at time t**7**, the gradient of the downhill road on which the vehicle is traveling increases, and the vehicle speed starts to increase. Then, at time t**8**, the vehicle speed exceeds the upper limit value of the target vehicle speed range. Thus, hydraulic braking force is generated so that the vehicle speed falls within the target vehicle speed range. Thereafter, the hydraulic pressure is stabilized at time t**9**. Note that the clearance C**1** (FIG. **2**) of the EPB **2** increases due to the generation of hydraulic braking force from time t**8** onward.
(45) Then, at time t**10**, the vehicle speed falls into the target vehicle speed range. Thereafter, at least one of the vehicle speed and the hydraulic pressure is stabilized from time t**11** to time t**12**, and the EPB **2** starts to actuate at time t**12**. Then, at time t**13**, the clearance C**1** (FIG. **2**) of the EPB **2**

becomes 0.
(46) Then, when the hydraulic braking force is set to 0 at time t**14**, the hydraulic braking force is replaced with electric braking force. That is, since the clearance C**1** (FIG. **2**) of the EPB **2** is 0, electric braking force equivalent to the hydraulic braking force is generated even if the hydraulic pressure becomes 0.
(47) Thereafter, at time t**15**, the gradient of the downhill road on which the vehicle is traveling decreases, and the vehicle speed starts to decrease. Then, at time t**16**, the vehicle speed falls below the lower limit value of the target vehicle speed range. Thus, the electric braking force is reduced so that the vehicle speed falls within the target vehicle speed range.
(48) Thereafter, the electric braking force is held at time t**17**. From this, the vehicle speed falls into the target vehicle speed range at time t**18**, and thereafter, the vehicle speed is stabilized from time t**19** onward.
(49) Next, the state of temporal change of each piece of information in a case where braking force is increased during DAC is described with reference to FIGS. **5**A to **5**C. FIGS. **5**A to **5**C are graphs schematically illustrating the state of temporal change in each piece of information in a case where braking force is increased during DAC in the embodiment.
(50) In the graph of FIGS. **5**A to **5**C, the horizontal axis represents time. The vertical axis in FIG. **5**A represents braking force (Nm: Newton meter). The vertical axis in FIG. **5**B represents an EPB motor current value (a current value of the motor **10** of the EPB **2**) generated by an instruction from the EPB-ECU **9**. The vertical axis in FIG. **5**C represents the stroke amount (movement amount of the propulsion shaft **18** (FIG. **2**)) of the EPB **2** acting according to an instruction from the EPB-ECU **9**.
(51) Hydraulic braking force is generated from time t**31** to time t**35**. At the same time, the EPB motor current value rapidly increases due to inrush current at time t**31**, temporarily stabilizes at time t**32**, then increases from time t**33** to time t**34** due to the propulsion shaft **18** abutting the piston **19** (that is, the clearance C**1** in FIG. **2** becoming 0), and becomes 0 at time t**34**. However, the increase in the EPB motor current value from time t**33** to time t**34** is for determining that the clearance C**1** (FIG. **2**) has become 0, and is not for intentionally increasing electric braking force.
(52) When the hydraulic braking force is set to 0 at time t**35**, the hydraulic braking force is replaced with electric braking force. That is, since the clearance C**1** (FIG. **2**) of the EPB **2** is 0, electric braking force equivalent to the hydraulic braking force is generated even if the hydraulic pressure becomes 0. Accordingly, the total braking force is equivalent before and after time t**35**. Note that the hydraulic braking force and the EPB motor current value are not intentionally simultaneously generated at time t**31**, and the EPB motor current value may be generated after the hydraulic braking force (hereinafter, the same shall apply).
(53) Thereafter, when the total braking force is increased, the hydraulic braking force is increased at time t**36**. This hydraulic braking force is maintained from time t**36** to time t**40**. At the same time, the EPB motor current value rapidly increases due to inrush current at time t**36**, temporarily stabilizes at time t**37**, then increases from time t**38** to time t**39** due to the clearance C**1** in FIG. **2** becoming 0, and becomes 0 at time t**39**.
(54) When the hydraulic braking force becomes 0 at time t**40**, the hydraulic braking force is replaced with electric braking force. That is, since the clearance C**1** (FIG. **2**) of the EPB **2** is 0, electric braking force equivalent to the hydraulic braking force is generated even if the hydraulic pressure becomes 0. Accordingly, the total braking force is equivalent before and after time t**40**.
(55) Thereafter, when the total braking force is increased, the hydraulic braking force is increased at time t**41**. This hydraulic braking force is maintained from time t**41** to time t**45**. At the same time, the EPB motor current value rapidly increases due to inrush current at time t**41**, temporarily stabilizes at time t**42**, then increases from time t**43** to time t**44** due to the clearance C**1** (FIG. **2**) becoming 0, and becomes 0 at time t**44**.
(56) When the hydraulic braking force becomes 0 at time t**45**, the hydraulic braking force is

replaced with electric braking force. That is, since the clearance C**1** (FIG. **2**) of the EPB **2** is 0, electric braking force equivalent to the hydraulic braking force is generated even if the hydraulic pressure becomes 0. Accordingly, the total braking force is equivalent before and after time t**45**.
(57) In this way, when at least one of the vehicle speed and the hydraulic pressure is stabilized after the hydraulic braking force is generated during DAC, the hydraulic braking force is replaced with electric braking force, so that the total braking force can be maintained while temporarily stopping the ESC-ACT **7** or the hydraulic brake device.
(58) Next, the state of temporal change of each piece of information in a case where braking force is reduced during DAC will be described with reference to FIGS. **6**A to **6**C. FIGS. **6**A to **6**C are graphs schematically illustrating the state of temporal change in each piece of information in a case where braking force is reduced during DAC in the embodiment. The contents of the vertical axis and the horizontal axis in FIGS. **6**A to **6**C are the same as those in FIGS. **5**A to **5**C.
(59) First, it is assumed that electric braking force is generated before time t**51**. Furthermore, the hydraulic braking force is always 0. When the electric braking force is reduced at time t**51**, the EPB motor current value is reduced to a predetermined current value by time t**52** (or may be reduced for a predetermined period of time, hereinafter the same shall apply) and is then set to 0. From this, the EPB stroke amount and the total braking force (=electric braking force) decrease. Thereafter, the total braking force is maintained until time t**53**.
(60) When the electric braking force is reduced at time t**53**, the EPB motor current value is reduced to a predetermined current value by time t**54** and is then set to 0. From this, the EPB stroke amount and the total braking force (=electric braking force) decrease. Thereafter, the total braking force is maintained until time t**55**.
(61) When the electric braking force is reduced at time t**55**, the EPB motor current value is reduced to a predetermined current value by time t**56** and is then set to 0. From this, the EPB stroke amount and the total braking force (=electric braking force) decrease. Thereafter, the total braking force is maintained.
(62) In this way, in a case where the total braking force is reduced after replacing hydraulic braking force with electric braking force during DAC, it is only necessary to reduce the electric braking force, and it is not necessary to generate the hydraulic braking force.
(63) Next, processing by the braking control device is described with reference to FIG. **7**. FIG. **7** is a flowchart depicting the processing by the braking control device (ESC-ECU **8** and EPB-ECU **9**) of the embodiment.
(64) First, in Step S**1**, the ESC-ECU **8** determines whether or not a DAC start operation has been performed by a user. The processing proceeds to Step S**2** when Yes and returns to Step S**1** when No.
(65) In Step S**2**, the ESC-ECU **8** performs DAC. That is, the ESC-ECU **8** controls the ESC-ACT **7** to adjust hydraulic braking force so that the vehicle speed falls within the target vehicle speed range.
(66) Next, in Step S**3**, the EPB-ECU **9** determines whether or not the hydraulic pressure or the vehicle speed has stabilized. The processing proceeds to Step S**4** when Yes and returns to Step S**2** when No.
(67) In Step S**4**, the EPB-ECU **9** controls the ESC-ACT **7** and the EPB **2** to replace the hydraulic braking force with electric braking force (time t**6** in FIGS. **4**A to **4**C).
(68) Next, in Step S**5**, the EPB-ECU **9** determines whether or not the vehicle speed exceeds the target vehicle speed range. The processing proceeds to Step S**6** when Yes and proceeds to Step S**9** when No.
(69) In Step S**6**, the ESC-ECU **8** controls the ESC-ACT **7** to adjust the hydraulic braking force so that the vehicle speed falls within the target vehicle speed range.
(70) Next, in Step S**7**, the EPB-ECU **9** determines whether or not the hydraulic pressure or the vehicle speed has stabilized. The processing proceeds to Step S**8** when Yes and returns to Step S**6**

when No.
(71) In Step S**8**, the EPB-ECU **9** controls the ESC-ACT **7** and the EPB **2** to replace the hydraulic braking force with electric braking force (time t**14** in FIGS. **4**A to **4**C).
(72) In Step S**9**, after No in Step S**5** and after Step S**8**, the EPB-ECU **9** determines whether or not the vehicle speed falls below the target vehicle speed range. The processing proceeds to Step S**10** when Yes and proceeds to Step S**11** when No.
(73) In Step S**10**, the EPB-ECU **9** controls the EPB **2** to reduce the electric braking force so that the vehicle speed falls within the target vehicle speed range (times t**16** to t**17** in FIGS. **4**A to **4**C).
(74) In Step S**11**, after No in Step S**9** and after Step S**10**, the ESC-ECU **8** determines whether or not the user has performed a DAC end operation. The processing proceeds to Step S**12** when Yes and returns to Step S**5** when No. In Step S**12**, the braking control device ends DAC.
(75) In this way, according to the braking control device (ESC-ECU **8** and EPB-ECU **9**) of the present embodiment, when at least one of the vehicle speed and the hydraulic pressure is stabilized after hydraulic braking force is first generated during DAC, the hydraulic braking force is replaced with electric braking force so that overheating of the hydraulic brake device can be suppressed. For a specific example, in FIGS. **4**A to **4**C, even during DAC, overheating of the hydraulic brake device can be suppressed by stopping the action of the hydraulic brake device (ESC-ACT **7**) from time t**6** to time t**8** or from time t**14** onward.
(76) In addition, during DAC, not electric braking force but hydraulic braking force with excellent responsiveness is generated at first. Thereafter, when the vehicle speed or the hydraulic pressure is stabilized, the hydraulic braking force is replaced with electric braking force which is excellent for maintaining braking force. From this, overheating of the hydraulic brake device can be suppressed without reducing braking responsiveness as compared with the prior art.
(77) In addition, in the prior art, in order to suppress overheating of the hydraulic brake device during DAC, for example, measures are taken to suppress performance or actuation time. According to the braking control device of the present embodiment, the necessity of such measures is reduced. From this, time in which DAC can continue can be increased.
(78) When the gradient of a downhill road increases and the vehicle speed exceeds the target vehicle speed range after hydraulic braking force is replaced with electric braking force, the hydraulic braking force is first adjusted so that the vehicle speed falls within the target vehicle speed range. Thereafter, when at least one of the vehicle speed and the hydraulic pressure is stabilized, the hydraulic braking force is replaced with the electric braking force, so that it is possible to flexibly counter the increase in the gradient of the downhill road.
(79) When the gradient of a downhill road on which the vehicle is traveling decreases and the vehicle speed falls below the target vehicle speed range after hydraulic braking force is replaced with electric braking force, the electric brake device is controlled to reduce the electric braking force so that the vehicle speed falls within the target vehicle speed range, thus making it possible to flexibly counter the decrease in the gradient of the downhill road.
(80) Although an embodiment of the present disclosure has been exemplified above, the above embodiment is merely an example, and is not intended to limit the scope of the disclosure. The above embodiment can be implemented in various other forms, and various omissions, substitutions, combinations, and changes can be made within a scope not departing from the gist of the disclosure. In addition, specifications (structure, type, number, and the like) of each configuration, shape, and the like can be appropriately changed and implemented.
(81) For example, in the above embodiment, a case of an EPB-type disc brake has been described as an example, but the present embodiment can also be applied to an EPB-type drum brake.
(82) Furthermore, in the above embodiment, a case where hydraulic braking force for four wheels is replaced with electric braking force has been described, but the present disclosure is not limited as such. In addition, for example, when the EPB is mounted on the two rear wheels, hydraulic braking force for the two rear wheels may be replaced with electric braking force, and hydraulic

braking force for the two front wheels may be the same as in the prior art. Also in this case, the effect of suppressing overheating due to a decrease in the actuation time of the motor and solenoids (various control valves) in the hydraulic brake device can be obtained.

Claims

1. A braking control device for application in a vehicle, the braking control device comprising: a hydraulic brake device configured to press a braking member using hydraulic pressure toward a braked member that rotates integrally with a wheel to generate hydraulic braking force; an electric brake device configured to press the braking member using driving force of a motor toward the braked member to generate electric braking force; an ESC-ECU configured to adjust the hydraulic braking force by controlling the hydraulic brake device so that a vehicle speed falls within a target vehicle speed range while the vehicle is traveling on a downhill road even without depression of a brake pedal by a driver; and an EPB-ECU configured to, when at least one of the vehicle speed and the hydraulic pressure is stabilized, control the hydraulic brake device and the electric brake device to replace the hydraulic braking force with the electric braking force, wherein when the vehicle speed exceeds the target vehicle speed range due to an increase in a gradient of the downhill road on which the vehicle is traveling after the hydraulic braking force is replaced with the electric braking force, the braking control device controls the hydraulic brake device to adjust the hydraulic braking force so that the vehicle speed falls within the target vehicle speed range when the vehicle speed exceeds the target vehicle speed range, and thereafter when at least one of the vehicle speed and the hydraulic pressure is stabilized or/and an absolute value of vehicle deceleration becomes equal to or smaller than a second predetermined value, controls the hydraulic brake device and the electric brake device to replace the hydraulic braking force with the electric braking force.
2. The braking control device according to claim 1, wherein the hydraulic brake device and the electric brake device have a common piston that can press the braking member using hydraulic pressure and the driving force of the motor, and the electric brake device has a propulsion shaft that can be brought into contact with and separated from the piston and that can press the piston toward the braking member using the driving force of the motor in a state in which the propulsion shaft is in contact with the piston, and the braking control device controls the hydraulic brake device to reduce the hydraulic braking force to 0 in a state in which the propulsion shaft is in contact with the piston, thereby the hydraulic braking force being replaced with the electric braking force.
3. The braking control device according to claim 1, wherein the braking control device controls the hydraulic brake device to reduce the hydraulic braking force to 0 in a state in which the electric brake device generates the electric braking force, thereby the hydraulic braking force being replaced with the electric braking force.
4. A braking control device for application in a vehicle, the braking control device comprising: a hydraulic brake device configured to press a braking member using hydraulic pressure toward a braked member that rotates integrally with a wheel to generate hydraulic braking force; an electric brake device configured to press the braking member using driving force of a motor toward the braked member to generate electric braking force; an ESC-ECU configured to adjust the hydraulic braking force by controlling the hydraulic brake device so that a vehicle speed falls within a target vehicle speed range while the vehicle is traveling on a downhill road even without depression of a brake pedal by a driver; and an EPB-ECU configured to, when at least one of the vehicle speed and the hydraulic pressure is stabilized, control the hydraulic brake device and the electric brake device to replace the hydraulic braking force with the electric braking force, wherein when vehicle acceleration exceeds a first predetermined value due to an increase in a gradient of the downhill road on which the vehicle is traveling after the hydraulic braking force is replaced with the electric braking force, the braking control device controls the hydraulic brake device to adjust the hydraulic braking force so that the vehicle acceleration becomes equal to or smaller than the first

predetermined value when the vehicle acceleration exceeds the first predetermined value, and thereafter when at least one of the vehicle speed and the hydraulic pressure is stabilized or/and an absolute value of vehicle deceleration becomes equal to or smaller than a second predetermined value, controls the hydraulic brake device and the electric brake device to replace the hydraulic braking force with the electric braking force.

5. A braking control device for application in a vehicle, the braking control device comprising: a hydraulic brake device configured to press a braking member using hydraulic pressure toward a braked member that rotates integrally with a wheel to generate hydraulic braking force; an electric brake device configured to press the braking member using driving force of a motor toward the braked member to generate electric braking force; an ESC-ECU configured to adjust the hydraulic braking force by controlling the hydraulic brake device so that a vehicle speed falls within a target vehicle speed range while the vehicle is traveling on a downhill road even without depression of a brake pedal by a driver; and an EPB-ECU configured to, when at least one of the vehicle speed and the hydraulic pressure is stabilized, control the hydraulic brake device and the electric brake device to replace the hydraulic braking force with the electric braking force, wherein when the vehicle speed falls below the target vehicle speed range due to a decrease in a gradient of the downhill road on which the vehicle is traveling after the hydraulic braking force is replaced with the electric braking force, the braking control device controls the electric brake device to reduce the electric braking force so that the vehicle speed falls within the target vehicle speed range.