United States Patent	12384342
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Kawai; Takuto

Braking control device for vehicle

Abstract

When it is diagnosed that a braking control device **50** functions normally, a command unit **70***f* transmits a braking force command value to drive units **60***a,* **60***b,* and a command unit **70***r* transmits the braking force command value to drive units **60***c,* **60***d.* Then, the drive units **60***a,* **60***b* drives braking mechanisms **30***a,* **30***b* according to the command value transmitted by the command unit **70***f,* and the drive units **60***c,* **60***d* drives braking mechanisms **30***c,* **30***d* according to the command value transmitted by the command unit **70***r.* Meanwhile, when it is diagnosed that the braking control device **50** does not function normally, at least one of the command units **70***f,* **70***r* executes backup control for compensating for a shortage of a braking force of a vehicle **10** for a braking request, which is caused by the braking control device **50** not functioning normally.

Inventors:	**Kawai; Takuto (Kariya, JP)**
Applicant:	**ADVICS CO., LTD.** (Kariya, JP)
Family ID:	**1000008748312**
Assignee:	**ADVICS CO., LTD. (Kariya, JP)**
Appl. No.:	**18/291024**
Filed (or PCT Filed):	**July 29, 2022**
PCT No.:	**PCT/JP2022/029369**
PCT Pub. No.:	**WO2023/008573**
PCT Pub. Date:	February 02, 2023

Prior Publication Data

Document Identifier	Publication Date
US 20240326764 A1	Oct. 03, 2024

Foreign Application Priority Data

Publication Classification

Int. Cl.: B60T8/92 (20060101); **B60T13/74** (20060101); **B60T17/22** (20060101)

U.S. Cl.:

CPC   **B60T8/92** (20130101); **B60T13/741** (20130101); **B60T17/221** (20130101); B60T2270/402 (20130101); B60T2270/413 (20130101)

Field of Classification Search

CPC: B60T (8/92); B60T (13/741); B60T (17/221); B60T (2270/402); B60T (2270/413)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2010/0204894	12/2009	Strengert et al.	N/A	N/A
2022/0388487	12/2021	Hwang	N/A	B60T 7/12
2023/0042441	12/2022	Fujita	N/A	B60T 13/741
2023/0129690	12/2022	Lee	701/34.4	B60T 8/885

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2010-534590	12/2009	JP	N/A

OTHER PUBLICATIONS

International Search Report mailed on Oct. 4, 2022 in PCT/JP2022/029369 filed on Jul. 29, 2022, 2 pages. cited by applicant

Primary Examiner: Amick; Jacob M

Attorney, Agent or Firm: Oblon, McClelland, Maier & Neustadt, L.L.P.

Background/Summary

TECHNICAL FIELD
(1) The present disclosure relates to a braking control device for a vehicle.
BACKGROUND ART
(2) In PTL 1, an example of a brake system is described, and the brake system separately regulates braking forces that are applied to four wheels provided to a vehicle. This brake system includes: four brake actuators, each of which corresponds to respective one of the four wheels; and four actuator control devices, each of which corresponds to respective one of the four brake actuators. The brake system further includes a system control device that derives a braking force command value. The system control device has two computers. When the braking force command value is

transmitted from such a system control device to the actuator control device, the actuator control device drives the brake actuator corresponding thereto on the basis of the received command value.
(3) There is a case where at least one control device of the system control device and the actuator control devices fails during travel of the vehicle, to which the above brake system is mounted. In this case, the actuator control device that does not fail drives the brake actuator corresponding thereto and thereby applies the braking force to the wheels. In this way, when at least one of the control devices fails, the vehicle can be stopped to ensure safety of an occupant.
CITATION LIST
Patent Literature
(4) PTL 1: JP2010-534590A
BRIEF SUMMARY
Technical Problem
(5) In recent years, in regard to the brake system with such a redundant configuration that the system control device has the plural computers, it has been desired to enable regulating the vehicle braking force in a manner to meet a driver's intention even when abnormality occurs to at least one of the control devices as described above. However, with the brake system described in PTL 1, there is a possibility that the vehicle braking force cannot be regulated in the manner to meet the driver's intention when the abnormality occurs to at least one of the control devices.
Solution to Problem
(6) Hereinafter, means to solve the above problem and operational effects thereof will be described.
(7) A braking control device for a vehicle that solves the above problem is a braking control device for a vehicle, the braking control device being applied to a vehicle including: a first braking mechanism that applies a braking force to a first wheel; and a second braking mechanism that applies a braking force to a second wheel. The braking control device for a vehicle includes: a first drive unit that drives the first braking mechanism according to a first command value and thereby applies the braking force to the first wheel, the first command value being a braking force command value to be applied to the first wheel; a second drive unit that drives the second braking mechanism according to a second command value and thereby applies the braking force to the second wheel, the second command value being a braking force command value to be applied to the second wheel; a first command unit that derives the first command value and the second command value on the basis of a braking request as a request for the braking force on the vehicle, can transmit the first command value to the first drive unit, and can transmit the second command value to the second drive unit; a second command unit that derives the first command value and the second command value on the basis of the braking request, can transmit the first command value to the first drive unit, and can transmit the second command value to the second drive unit; and a diagnostic unit that diagnoses whether the braking control device functions normally. In the case where the diagnostic unit diagnoses that the braking control device functions normally, the first command unit transmits the first command value to the first drive unit, the first drive unit drives the first braking mechanism according to the first command value transmitted by the first command unit, the second command unit transmits the second command value to the second drive unit, and the second drive unit drives the second braking mechanism according to the second command value transmitted by the second command unit. In the case where the diagnostic unit diagnoses that the braking control device does not function normally, at least one of the first command unit and the second command unit executes backup control for compensating for a shortage of the braking force of the vehicle for the braking request, which is caused by the braking control device not functioning normally.
(8) In the case where some abnormality occurs to the braking control device, there is a possibility that the braking force corresponding to a required value of the braking force cannot be generated to the vehicle. In regard to this point, in the above configuration, when it is diagnosed that the braking control device does not function normally, the backup control is executed. In this way, it is possible

to suppress the shortage of the braking force, which is caused by the braking control device not functioning normally. Therefore, according to the configuration, even in the case where some abnormality occurs to the braking control device, the braking force of the vehicle can be regulated according to the required value of the braking force.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a schematic view of a vehicle that includes a braking control device in an embodiment.
(2) FIG. **2** is a schematic diagram illustrating communication paths between each of a first command unit and a second command unit and each of a first drive unit and a second drive unit.
(3) FIG. **3** is a table illustrating relationships between diagnostic result patterns and command value transmission modes.
(4) FIG. **4** is a flowchart illustrating a series of processing flows executed when the diagnostic result pattern is classified.
(5) FIG. **5** is a flowchart illustrating a series of processing flows executed when a braking request is present under a situation where some abnormality occurs to the braking control device.
DESCRIPTION OF EMBODIMENTS
(6) A description will hereinafter be made on an embodiment of a braking control device for a vehicle with reference to the drawings.
(7) <Vehicle>
(8) FIG. **1** illustrates a vehicle **10** that includes a braking control device **50**. The vehicle **10** includes, in addition to the braking control device **50**, four wheels **20** (**20***a* to **20***d*), four braking mechanisms **30** (**30***a* to **30***d*), a braking operation member **40**, and a stroke sensor **41**.
(9) <Braking Mechanism **30**>
(10) The braking mechanism **30** applies a braking force to the corresponding wheel **20**. Of the four braking mechanisms **30**, the braking mechanism **30***a* corresponds to the right front wheel **20***a*, and the braking mechanism **30***b* corresponds to the left front wheel **20***b*. In addition, the braking mechanism **30***c* corresponds to the right rear wheel **20***c*, and the braking mechanism **30***d* corresponds to the left rear wheel **20***d*.
(11) As illustrated in FIG. **1**, the braking mechanism **30** includes: a rotary body **31** that rotates together with the wheel **20**; a friction member **32** that does not rotate together with the wheel **20**; and an electric motor **33** that drives the friction member **32**. By driving the electric motor **33**, the friction member **32** is displaced in a direction to approach the rotary body **31** or is displaced in a direction away from the rotary body **31**. The braking force is applied to the wheel **20** when the friction member **32** is brought close to the rotary body **31**. When a force that presses the friction member **32** against the rotary body **31** is increased by driving the electric motor **33**, the braking force that is applied to the wheel **20** is increased. The braking mechanism **30** is an electromechanical brake (EMB), for example. In this embodiment, the braking mechanism **30** is a disc brake. However, in another embodiment, the braking mechanism **30** may be a drum brake.
(12) <Braking Operation Member **40**>
(13) As illustrated in FIG. **1**, the braking operation member **40** is a member that is operated when a driver requests braking for the vehicle **10**. The braking operation member **40** is a brake pedal, for example. The stroke sensor **41** detects an operation amount of the braking operation member **40** by the driver. The stroke sensor **41** outputs a detection signal indicating the detected operation amount to the braking control device **50**.
(14) Instead of the stroke sensor **41**, an operation force sensor may be provided to detect an operation force that is input to the braking operation member **40** from the driver, and a detection

signal of the operation force sensor may be input to the braking control device **50**. Needless to say, the detection signals of both the stroke sensor **41** and the operation force sensor may be input to the braking control device **50**.

(15) <Braking Control Device **50**>

(16) As illustrated in FIG. **1**, the braking control device **50** includes: the same number of drive units **60** (**60a** to **60d**) as the braking mechanisms **30**; and two command units **70** (**70f, 70r**). In the braking control device **50**, the four drive units **60** and the two command units **70** correspond to a CPU. However, the command unit **70** may be a hardware circuit that is designed specifically.

(17) The drive unit **60** controls the corresponding braking mechanism **30**. That is, of the four drive units **60a**, the drive unit **60a** controls the braking mechanism **30a** of the four braking mechanisms **30**. In addition, the drive unit **60b** controls the braking mechanism **30b**, the drive unit **60c** controls the braking mechanism **30c**, and the drive unit **60d** controls the braking mechanism **30d**. The drive unit **60** is arranged near the corresponding braking mechanism **30**. The drive unit **60** and the braking mechanism **30** that correspond to each other are preferably unitized. For example, the drive unit **60a** is preferably unitized with the braking mechanism **30a**.

(18) The drive unit **60** drives the corresponding braking mechanism **30** according to a command value indicating a magnitude of the braking force to be applied to the wheel **20**. In this way, each of the braking forces applied to the four wheels **20** is regulated. For example, the drive unit **60a** drives the braking mechanism **30a** for the right front wheel according to the braking force command value to be applied to the right front wheel **20a**. In this way, the braking force that is applied to the right front wheel **20a** is regulated.

(19) The two command units **70** are mounted to a command control unit **100**. The command control unit **100** is an ECU, for example. As illustrated in FIG. **1**, the command control unit **100** is a separate unit from the four braking mechanisms **30**, to which the four drive units **60** are provided, respectively. In the command control unit **100**, the two command units **70** are connected in a mutually communicable manner.

(20) Of the two command units **70**, the command unit **70f** is connected to the four drive units **60** via communication lines. The command unit **70r** is also connected to the four drive units **60** via communication lines. For example, the communication lines for connecting the command unit **70f** to the drive units **60** and the communication lines for connecting the command unit **70r** to the drive units **60** are partially shared. In another embodiment, both of the communication lines may be completely independent of each other. In the former case, one input/output port is provided to each of the drive units **60** for communication with the two command units **70**. In the latter case, two input/output ports are provided to each of the drive units **60** for the communication with the two command units **70**.

(21) When a braking request is present, the command unit **70f** derives a required braking force as a required value of the braking force of the vehicle **10**. For example, in the case where the driver requests generation of the braking force through the operation of the braking operation member **40**, the command unit **70f** derives the required braking force on the basis of the detection signal output from the stroke sensor **41**. Meanwhile, when deceleration of the vehicle **10** is requested from another control device, the command unit **70f** determines the presence of the braking request and derives, as the required braking force, the braking force that corresponds to the required deceleration. Next, based on the required braking force, the command unit **70f** derives the braking force command value to be applied to each of the four wheels **20**. The command unit **70f** can transmit the braking force command value to be applied to each of the four wheels **20** to each of the four drive units **60**.

(22) The braking force command value to be applied to each of the four wheels **20** is the braking force that is acquired by dividing the required braking force to the four wheels **20**. The command values for the four wheels **20** may be the same value or may be different values. The command unit **70f** preferably derives the command value for each of the four wheels **20** in consideration of a

condition of the vehicle **10**, a road surface condition, and the like. During execution of ABS control or the like, a value as a sum of the command values of the braking forces to be applied to the four wheels **20** may be a different value from the required braking force.

(23) The command unit **70***f* has a diagnostic unit **80***f* (**80**) that diagnoses whether the four drive units **60** function normally. The diagnostic unit **80***f* diagnoses whether the four drive units **60** function normally through exchange of signals with the four drive units **60**.

(24) A description will be made on an example of a method for diagnosing whether the drive unit **60** functions normally. Here, a description will be made on, as an example, a case where the diagnostic unit **80***f* diagnoses whether the drive unit **60***a* functions normally.

(25) The diagnostic unit **80***f* transmits a confirmation signal to the drive unit **60***a*. When the drive unit **60***a* is normal, the drive unit **60***a* transmits, to the diagnostic unit **80***f*, a response signal to the received confirmation signal. In the case where the diagnostic unit **80***f* receives the response signal that is a reply to the confirmation signal transmitted to the drive unit **60***a*, just as described, the diagnostic unit **80***f* diagnoses that the drive unit **60***a* functions normally. On the other hand, in the case where the diagnostic unit **80***f* cannot receive the response signal that is the reply to the confirmation signal transmitted to the drive unit **60***a*, the diagnostic unit **80***f* diagnoses that the drive unit **60***a* does not function normally.

(26) The following cases are examples of a cause that inhibits the diagnostic unit **80***f* from receiving the response signal from the drive unit **60***a*. A case where abnormality occurs to the drive unit **60***a*, such as failure of the drive unit **60***a* A case where the communication line that connects the command unit **70***f* having the diagnostic unit **80***f* and the drive unit **60***a* is disconnected A case where the signal exchanged via the communication line is superimposed with noise

(27) When the confirmation signal, which is transmitted from the diagnostic unit **80***f* to the drive unit **60***a*, is superimposed with the noise, in some cases, the drive unit **60***a* cannot recognize the received signal as the confirmation signal and does not transmit the response signal to the diagnostic unit **80***f*. In addition, when the response signal, which is transmitted from the drive unit **60***a* to the diagnostic unit **80***f*, is superimposed with the noise, in some cases, the diagnostic unit **80***f* cannot recognize the received signal as the response signal.

(28) In a similar manner for the drive unit **60***a*, the diagnostic unit **80***f* diagnoses whether each of the other drive units **60***b* to **60***d* functions normally through the exchange of the signal with each of the other drive units **60***b* to **60***d*.

(29) Similar to the command unit **70***f*, the command unit **70***r* derives the required braking force when the braking request is present. Next, based on the required braking force, the command unit **70***r* derives the braking force command value to be applied to each of the four wheels **20**. The command unit **70***r* can transmit the braking force command value to be applied to each of the four wheels **20** to each of the four drive units **60**. Similar to the command unit **70***f*, the command unit **70***r* has a diagnostic unit **80***r* (**80**) that diagnoses whether the four drive units **60** function normally. The diagnostic unit **80***r* diagnoses whether the four drive units **60** function normally through exchange of signals with the four drive units **60**. The command units **70***f*, **70***r* share diagnostic results by the diagnostic units **80***f*, **80***r* thereof by exchanging information to each other.

(30) The required braking force that is derived by the command unit **70***f* has the same value as the required braking force that is derived by the command unit **70***r*. Furthermore, both of the two command units **70***f*, **70***r* can transmit the command value to each of the four drive units **60***a* to **60***d*. Accordingly, even in the case where one command unit of the two command units **70***f*, **70***r* can no longer transmit the braking force command value to any drive unit of the four drive units **60***a* to **60***d*, the other command unit can transmit the braking force command value to such a drive unit. Regarding this point, it can be said that the braking control device **50** in this embodiment adopts a redundant configuration to occurrence of the abnormality.

(31) Under a situation where the braking control device **50** functions normally, the following transmission modes are available for the two command units **70***f*, **70***r* to transmit the braking force

command value when the braking request is present. The command unit **70***f* transmits the braking force command value to each of the drive units **60***a*, **60***b*, which respectively correspond to the front wheels **20***a*, **20***b*, but does not transmit the braking force command value to each of the drive units **60***c*, **60***d*, which respectively correspond to the rear wheels **20***c*, **20***d*. Meanwhile, the command unit **70***r* transmits the braking force command value to each of the drive units **60***c*, **60***d*, which respectively correspond to the rear wheels **20***c*, **20***d*, but does not transmit the braking force command value to each of the drive units **60***a*, **60***b*, which respectively correspond to the front wheels **20***a*, **20***b*. Based on these points, the command unit **70***f* is the CPU for primarily transmitting the braking force command value to each of the front wheels **20***a*, **20***b*, and the command unit **70***r* is the CPU for primarily transmitting the braking force command value to each of the rear wheels **20***c*, **20***d*. In other words, the command unit **70***f* is the CPU that serves as a backup capable of transmitting the braking force command value to each of the rear wheels **20***c*, **20***d*, and the command unit **70***r* is the CPU that serves as a backup capable of transmitting the braking force command value to each of the front wheels **20***a*, **20***b*. In this embodiment, the transmission modes of the braking force command value by the two command units **70***f*, **70***r* are changed according to a content of the abnormality of the braking control device **50** that is classified on the basis of the diagnostic results by the two diagnostic units **80***f*, **80***r*.

(32) <Relationship Between Diagnostic Result by Diagnostic Unit **80** and Backup Control>

(33) Next, a description will be made on a relationship between the diagnostic result by the diagnostic unit **80** and the transmission mode of the braking force command value by the command unit **70** with reference to FIG. **2** and FIG. **3**. In order to facilitate understanding of the description, FIG. **2** and FIG. **3** focus on the two command units **70** (**71**, **72**) and the two drive units **60** (**61**, **62**).

(34) In FIG. **2**, the first command unit **71** corresponds to one of the two command units **70***f*, **70***r*, and the second command unit **72** corresponds to the other of the two command units **70***f*, **70***r*. In the case where the first command unit **71** corresponds to the command unit **70***f*, the first drive unit **61** corresponds to the drive unit corresponding to the right front wheel **20***a* or the left front wheel **20***b*, and the second drive unit **62** corresponds to the drive unit corresponding to the right rear wheel **20***c* or the left rear wheel **20***d*. In the above case, the wheel **20** and the braking mechanism **30** corresponding to the first drive unit **61** respectively correspond to a "first wheel" and a "first braking mechanism", and the wheel **20** and the braking mechanism **30** corresponding to the second drive unit **62** respectively correspond to a "second wheel" and a "second braking mechanism".

(35) Eight patterns illustrated in FIG. **3** are provided as diagnostic result patterns by the diagnostic unit **80**.

(36) A first pattern corresponds to a case where a first diagnostic unit **81** diagnoses that the first drive unit **61** functions normally and where a second diagnostic unit **82** diagnoses that the second drive unit **62** functions normally. When the diagnostic result pattern is the first pattern, the first command unit **71** transmits, to the first drive unit **61**, a first command value that is the braking force command value to be applied to the first wheel. In addition, the second command unit **72** transmits, to the second drive unit **62**, a second command value that is the braking force command value to be applied to the second wheel. Meanwhile, the first command unit **71** does not transmit the second command value to the second drive unit **62**. Similarly, the second command unit **72** does not transmit the first command value to the first drive unit **61**.

(37) Then, the first drive unit **61** drives the first braking mechanism according to the first command value transmitted by the first command unit **71**. The second drive unit **62** drives the second braking mechanism according to the second command value transmitted by the second command unit **72**. In the first pattern, neither the diagnostic result of the second drive unit **62** by the first diagnostic unit **81** nor the diagnostic result of the first drive unit **61** by the second diagnostic unit **82** affects the command value transmission modes by the first command unit **71** and the second command unit **72**.

(38) A second pattern corresponds to a case where the first diagnostic unit **81** diagnoses that both

the first drive unit **61** and the second drive unit **62** function normally and where the second diagnostic unit **82** diagnoses that the second drive unit **62** does not function normally. When the diagnostic result pattern is the second pattern, it can be assumed that abnormality occurs to communication between the second command unit **72** and the second drive unit **62** despite a fact that the second drive unit **62** itself is normal. When the diagnostic result pattern is the second pattern, the first command unit **71** transmits the first command value to the first drive unit **61** and transmits the second command value to the second drive unit **62**. Meanwhile, the second command unit **72** does not transmit the first command value to the first drive unit **61**. Similarly, the second command unit **72** does not transmit the second command value to the second drive unit **62**.

(39) Then, the first drive unit **61** drives the first braking mechanism according to the first command value transmitted by the first command unit **71**. The second drive unit **62** drives the second braking mechanism according to the second command value transmitted by the first command unit **71**. In the second pattern, the diagnostic result of the first drive unit **61** by the second diagnostic unit **82** does not affect the command value transmission modes by the first command unit **71** and the second command unit **72**.

(40) A third pattern corresponds to a case where the first diagnostic unit **81** diagnoses that the first drive unit **61** functions normally and where both the first diagnostic unit **81** and the second diagnostic unit **82** diagnose that the second drive unit **62** does not function normally. When the diagnostic result pattern is the third pattern, it can be assumed that the abnormality occurs to the second drive unit **62**. When the diagnostic result pattern is the third pattern, the first command unit **71** increases the first command value according to a magnitude of the second command value. In other words, the first command unit **71** increases and corrects the first command value according to the magnitude of the second command value. An increase correction amount of the first command value in this case may be the same amount as the second command value derived by the first command unit **71** or may be a product of the second command value and a predetermined rate. The predetermined rate is preferably a positive value less than 1. Then, the first command unit **71** transmits the corrected first command value to the first drive unit **61**. In this case, the first command unit **71** does not transmit the second command value to the second drive unit **62**. In addition, the second command unit **72** does not transmit the first command value to the first drive unit **61**. Similarly, the second command unit **72** does not transmit the second command value to the second drive unit **62**.

(41) Then, the first drive unit **61** drives the first braking mechanism according to the first command value transmitted by the first command unit **71**. In this case, the first wheel is applied with the braking force that should be distributed to the second wheel in addition to the braking force distributed to the first wheel. Meanwhile, since the second command value is not transmitted to the second drive unit **62**, the second braking mechanism is not driven. As a result, the braking force is not applied to the second wheel. In the third pattern, the diagnostic result of the first drive unit **61** by the second diagnostic unit **82** does not affect the command value transmission modes by the first command unit **71** and the second command unit **72**.

(42) A fourth pattern corresponds to a case where the first diagnostic unit **81** diagnoses that the first drive unit **61** does not function normally and that the second drive unit **62** functions normally. The fourth pattern also corresponds to a case where the second diagnostic unit **82** diagnoses that the first drive unit **61** functions normally and that the second drive unit **62** does not function normally. When the diagnostic result pattern is the fourth pattern, it can be assumed that the abnormality occurs to communication between the first command unit **71** and the first drive unit **61** despite a fact that the first drive unit **61** itself is normal. It can also be assumed that the abnormality occurs to the communication between the second command unit **72** and the second drive unit **62** despite the fact that the second drive unit **62** itself is normal. When the diagnostic result pattern is the fourth pattern, the first command unit **71** transmits the second command value to the second drive unit **62**, and the second command unit **72** transmits the first command value to the first drive unit **61**.

Meanwhile, the first command unit **71** does not transmit the first command value to the first drive unit **61**. Similarly, the second command unit **72** does not transmit the second command value to the second drive unit **62**.

(43) Then, the first drive unit **61** drives the first braking mechanism according to the first command value transmitted by the second command unit **72**. The second drive unit **62** drives the second braking mechanism according to the second command value transmitted by the first command unit **71**.

(44) A fifth pattern corresponds to a case where the first diagnostic unit **81** diagnoses that the first drive unit **61** does not function normally and that the second drive unit **62** functions normally. The fifth pattern also corresponds to a case where the second diagnostic unit **82** diagnoses that none of the first drive unit **61** and the second drive unit **62** functions normally. When the diagnostic result pattern is the fifth pattern, it can be predicted that the abnormality occurs to the first drive unit **61**. It can also be predicted that the abnormality occurs to the communication between the second command unit **72** and the second drive unit **62** despite the fact that the second drive unit **62** itself is normal. When the diagnostic result pattern is the fifth pattern, the first command unit **71** increases the second command value according to a magnitude of the first command value. In other words, the first command unit **71** increases and corrects the second command value according to the magnitude of the first command value. An increase correction amount of the second command value in this case may be the same amount as the first command value derived by the first command unit **71** or may be a product of the first command value and a predetermined rate. The predetermined rate is preferably a positive value less than 1. Then, the first command unit **71** transmits the corrected second command value to the second drive unit **62**. In this case, the first command unit **71** does not transmit the first command value to the first drive unit **61**. In addition, the second command unit **72** does not transmit the first command value to the first drive unit **61**. Similarly, the second command unit **72** does not transmit the second command value to the second drive unit **62**.

(45) Then, the second drive unit **62** drives the second braking mechanism according to the second command value transmitted by the first command unit **71**. In this case, the second wheel is applied with the braking force that should be distributed to the first wheel in addition to the braking force distributed to the second wheel. Meanwhile, since the first command value is not transmitted to the first drive unit **61**, the first braking mechanism is not driven. As a result, the braking force is not applied to the first wheel.

(46) A sixth pattern corresponds to a case where the first diagnostic unit **81** diagnoses that the first drive unit **61** does not function normally and where the second diagnostic unit **82** diagnoses that both the first drive unit **61** and the second drive unit **62** function normally. When the diagnostic result pattern is the sixth pattern, the first command unit **71** does not transmit the first command value to the first drive unit **61**. Similarly, the first command unit **71** does not transmit the second command value to the second drive unit **62**. Meanwhile, the second command unit **72** transmits the first command value to the first drive unit **61** and transmits the second command value to the second drive unit **62**.

(47) Then, the first drive unit **61** drives the first braking mechanism according to the first command value transmitted by the second command unit **72**. In addition, the second drive unit **62** drives the second braking mechanism according to the second command value transmitted by the second command unit **72**.

(48) A seventh pattern corresponds to a case where both the first diagnostic unit **81** and the second diagnostic unit **82** diagnose that the first drive unit **61** does not function normally and where the second diagnostic unit **82** diagnoses that the second drive unit **62** functions normally. When the diagnostic result pattern is the seventh pattern, the second command unit **72** increases the second command value according to the magnitude of the first command value. Then, the second command unit **72** transmits the corrected second command value to the second drive unit **62**. In this

case, the second command unit **72** does not transmit the first command value to the first drive unit **61**. The first command unit **71** does not transmit the first command value to the first drive unit **61**, either. Similarly, the first command unit **71** does not transmit the second command value to the second drive unit **62**.

(49) Then, the second drive unit **62** drives the second braking mechanism according to the second command value transmitted by the second command unit **72**. In this case, the second wheel is applied with the braking force that should be distributed to the first wheel in addition to the braking force distributed to the second wheel. Meanwhile, since the first command value is not transmitted to the first drive unit **61**, the first braking mechanism is not driven. As a result, the braking force is not applied to the first wheel.

(50) An eighth pattern corresponds to a case where the first diagnostic unit **81** diagnoses that none of the first drive unit **61** and the second drive unit **62** functions normally. It also corresponds to a case where the second diagnostic unit **82** diagnoses that the first drive unit **61** functions normally and that the second drive unit **62** does not function normally. When the diagnostic result pattern is the eighth pattern, the second command unit **72** increases the first command value according to the magnitude of the second command value. Then, the second command unit **72** transmits the corrected first command value to the first drive unit **61**. In this case, the second command unit **72** does not transmit the second command value to the second drive unit **62**. In addition, the first command unit **71** does not transmit the first command value to the first drive unit **61**. Similarly, the first command unit **71** does not transmit the second command value to the second drive unit **62**.

(51) Then, the first drive unit **61** drives the first braking mechanism according to the first command value transmitted by the second command unit **72**. In this case, the first wheel is applied with the braking force that should be distributed to the second wheel in addition to the braking force distributed to the first wheel. Meanwhile, since the second command value is not transmitted to the second drive unit **62**, the second braking mechanism is not driven. As a result, the braking force is not applied to the second wheel.

(52) As it has been described so far, in the case where the diagnostic result pattern is not the first pattern, it can be determined that the braking control device **50** does not function normally. In such a case, the first command unit **71** and the second command unit **72** compensate for a shortage of the required braking force caused by accompanying that the braking control device **50** not functioning normally. In the following description, processing that is executed by at least one of the first command unit **71** and the second command unit **72** to compensate for the shortage of the required braking force, just as described, will be referred to as "backup control".

(53) <Processing Flow in Classifying Diagnostic Result Patterns>

(54) A description will be made on a flow of processing, which is executed by the first command unit **71** in predetermined control cycles when the braking request is not input to the braking control device **50**, with reference to FIG. **4**. Similar processing to the series of such processing is executed by the second command unit **72**. In the description with reference to FIG. **4**, one of the two command units **70***f*, **70***r* corresponds to the first command unit **71**, and the other corresponds to the second command unit **72**.

(55) In the series of the processing, in first step S**11**, the first command unit **71** diagnoses whether the drive unit **60** functions normally for each of the drive units **60**. Thereafter, in step S**12**, the first command unit **71** communicates with the second command unit **72** and thereby acquires the diagnostic results of the four drive units **60** by the second diagnostic unit **82** in the second command unit **72**.

(56) The second command unit **72** also diagnoses whether the drive unit **60** functions normally for each of the drive units **60**. Then, the second command unit **72** communicates with the first command unit **71** and thereby acquires the diagnostic results of the four drive units **60** by the first diagnostic unit **81** in the first command unit **71**.

(57) In step S**13**, the first command unit **71** classifies the diagnostic result pattern on the basis of

the diagnostic result by the first diagnostic unit **81** and the diagnostic result by the second diagnostic unit **82**. For example, the first command unit **71** classifies the diagnostic result pattern by referring to a table such as the one in FIG. **3**. Then, in the case where the diagnostic result pattern is the first pattern, the first diagnostic unit **81** in the first command unit **71** can determine that the braking control device **50** functions normally. Meanwhile, in the case where the diagnostic result pattern is the pattern other than the first pattern, the first diagnostic unit **81** in the first command unit **71** can determine that the braking control device **50** does not function normally. Thereafter, the first command unit **71** terminates the series of the processing once.

(58) Similar to the first diagnostic unit **81**, the second diagnostic unit **82** in the second command unit **72** also classifies the diagnostic result pattern. The result of the classification by the second diagnostic unit **82** is the same as the result of the classification by the first diagnostic unit **81**.

(59) <Processing Flow in Executing Backup Control>

(60) A description will be made on a flow of processing, which is executed by the first command unit **71** when the braking control device **50** receives the braking request, with reference to FIG. **5**. A series of the processing illustrated in FIG. **5** is processing that is started when the braking request is present under a situation where some abnormality occurs to the braking control device **50**. Similar processing to the series of such processing is executed by the second command unit **72**. In the description with reference to FIG. **5**, one of the two command units **70***f*, **70***r* corresponds to the first command unit **71**, and the other corresponds to the second command unit **72**.

(61) In the series of the processing, in first step S**21**, the first command unit **71** derives the required braking force. Next, in step S**22**, based on the required braking force, the first command unit **71** derives the braking force command value to be applied to each of the four wheels **20**. That is, the first command unit **71** derives the first command value and the second command value. Here, the first command unit **71** derives each of the command values under the assumption that the braking control device **50** functions normally.

(62) Then, in step S**23**, the first command unit **71** executes the backup control. The first command unit **71** executes the backup control that corresponds to the diagnostic result pattern classified through the execution of the series of the processing illustrated in FIG. **4**. For example, when the diagnostic result pattern is the second pattern, the first command unit **71** transmits the first command value to the first drive unit **61** and transmits the second command value to the second drive unit **62**. When the diagnostic result pattern is the fifth pattern, the first command unit **71** increases and corrects the second command value according to the magnitude of the first command value, and transmits the increased and corrected second command value to the second drive unit **62**.

(63) After the backup control is executed, just as described, the first command unit **71** allows the processing to proceed to step S**24**. In step S**24**, the first command unit **71** determines whether the required braking force is 0 (zero). That is, the first command unit **71** determines whether the braking request is no longer present. If the required braking force is larger than 0 (zero) (S**24**: NO), it can be determined that the braking request is still present, and thus the first command unit **71** allows the processing to proceed to step S**21**. On the other hand, if the required braking force is 0 (zero) (S**24**: YES), it can be determined that the braking request is no longer present, and thus the first command unit **71** terminates the series of the processing.

Action and Effects in this Embodiment

(64) When the braking control device **50** does not function normally, it may not be possible to apply the same magnitude of the braking force as the required braking force to the vehicle **10**. In regard to this point, when it is diagnosed that the braking control device **50** does not function normally, the braking control device **50** executes the backup control.

(65) For example, in the case where the abnormality occurs to the communication between the command unit **70***f* and the drive unit **60***a*, the command unit **70***f* can no longer transmit the braking force command value to the drive unit **60***a*, and thus the braking force is no longer applied to the

right front wheel **20***a*. In this case, as the backup control, the braking force command value is transmitted from the command unit **70***r* to the drive unit **60***a*. Accordingly, the drive unit **60***a* can drive the braking mechanism **30***a* on the basis of the command value transmitted by the command unit **70***r*. Thus, even in the case where the abnormality occurs to the communication between the command unit **70***f* and the drive unit **60***a*, the braking force can be applied to the right front wheel **20***a*.

(66) In addition, when the abnormality occurs to the drive unit **60***a*, the drive unit **60***a* can still receive the command value transmitted by the command unit **70***f* but can no longer drive the braking mechanism **30***a*. In this case, as the backup control, the transmission of the command value to the drive unit **60***a* is stopped, and then the command value to be transmitted to the drive unit other than the drive unit **60***a*, such as the drive unit **60***c*, is increased. In detail, the command value to the drive unit **60***c* is increased and corrected according to a magnitude of the command value to the drive unit **60***a*. Then, the increased and corrected command value is transmitted to the drive unit **60***c*. Thereafter, the braking mechanism **30***c* is driven according to the increased and corrected command value. As a result, the braking force applied to the right rear wheel **20***c* is increased. Thus, even when the braking force cannot be applied to the right front wheel **20***a*, it is possible to suppress a discrepancy between the actual braking force of the vehicle **10** and the required braking force.

(67) From what have been described so far, the backup control is executed when the braking control device **50** does not function normally. In this way, it is possible to suppress a shortage of the braking force, which is caused by the braking control device **50** not functioning normally. Therefore, even in the case where some abnormality occurs to the braking control device **50**, the braking force of the vehicle **10** can be regulated in a manner to meet the intention of the braking request.

(68) In this embodiment, the following effect can further be exerted.

(69) (1) In the braking control device **50**, the diagnostic unit **80**, which diagnoses whether the drive unit **60** functions normally, is provided to the command control unit **100**. Accordingly, the drive unit **60** can be implemented by the simple CPU that only controls the braking mechanism **30** according to the received braking force command value.

Modified Examples

(70) The above embodiment can be implemented with the following modifications. The above embodiment and the following modified examples can be implemented in combination with each other within the scope that is not technically contradictory. As described above, the command unit **70***f* transmits the confirmation signal to the drive units **60***a*, **60***b*. In the case where the drive units **60***a*, **60***b* can receive the confirmation signal, it can be determined that the command unit **70***f* functions normally. On the other hand, in the case where the drive units **60***a*, **60***b* cannot receive the confirmation signal, it can be determined that the command unit **70***f* does not function normally. Thus, each of the drive units **60***a*, **60***b* may diagnose whether the command unit **70***f* functions normally on the basis of whether the confirmation signal can be received. Then, in the case where the drive units **60***a*, **60***b* diagnose that the command unit **70***f* does not function normally, the drive units **60***a*, **60***b* may request the command unit **70***r* to transmit the command value and may drive the braking mechanisms **30***a*, **30***b*, respectively, according to the command value transmitted by the command unit **70***r*. In this way, even when the abnormality occurs to the command unit **70***f*, the braking mechanisms **30***a*, **30***b* can be driven. In this case, it can be said that the drive units **60***a*, **60***b* each have some of the function of the "diagnostic unit". Here, in the case where the drive units **60***a*, **60***b* can receive the confirmation signal from the command unit **70***f*, the drive units **60***a*, **60***b* may not accept the command value from the command unit **70***r*. According to this, even when the abnormality occurs to the command unit **70***r*, which in turn transmits the abnormal command value to the drive units **60***a*, **60***b*, the drive units **60***a*, **60***b* can drive the braking mechanisms **30***a*, **30***b*, respectively, according to the command value of the command unit **70***f*, which is normal. As

described above, the command unit **70**r transmits the confirmation signal to the drive units **60**c, **60**d. In the case where the drive units **60**c, **60**d can each receive the confirmation signal, it can be determined that the command unit **70**r functions normally. On the other hand, in the case where the drive units **60**c, **60**d cannot receive the confirmation signal, it can be determined that the command unit **70**r does not function normally. Thus, each of the drive units **60**c, **60**d may diagnose whether the command unit **70**r functions normally on the basis of whether the confirmation signal can be received. Then, in the case where the drive units **60**c, **60**d diagnose that the command unit **70**r does not function normally, the drive units **60**c, **60**d may request the command unit **70**f to transmit the command value and may drive the braking mechanisms **30**c, **30**d, respectively, according to the command value transmitted by the command unit **70**f. In this way, even when the abnormality occurs to the command unit **70**r, the braking mechanisms **30**c, **30**d can be driven. In this case, it can be said that the drive units **60**c, **60**d each have some of the function of the "diagnostic unit". Here, in the case where the drive units **60**c, **60**d can receive the confirmation signal from the command unit **70**r, the drive units **60**c, **60**d may not accept the command value from the command unit **70**f. According to this, even when the abnormality occurs to the command unit **70**f, which in turn transmits the abnormal command value to the drive units **60**c, **60**d, the drive units **60**c, **60**d can drive the braking mechanisms **30**c, **30**d, respectively, according to the command value of the command unit **70**r, which is normal. The diagnostic unit **80** may be mounted to a control unit other than the command unit **70**. In addition, the command unit **70**f and the command unit **70**r may be mounted to different control units. Furthermore, the command units **70**f, **70**r and the drive units **60**a to **60**d may be mounted to the same control unit. As it has been described with reference to FIG. **2** and FIG. **3**, when relationships among the two drive units **60** and the two command units **70** are considered, only one type of the backup control is available for the single diagnostic result pattern. Meanwhile, when relationships among the two command units **70** and the four drive units **60** are considered, plural types of the backup control are available for the single diagnostic result pattern. Hereinafter, as an example, a brief description will be made on the backup control that can be executed by the command unit **70**f and the command unit **70**r when the two diagnostic units **80** diagnose that the drive unit **60**a corresponding to the right front wheel **20**a does not function normally.

(71) Firstly, as the backup control, the command unit **70**r increases the braking force command value for the drive unit **60**c according to the magnitude of the braking force command value for the drive unit **60**a. In this case, the braking force that should be applied to the right front wheel **20**a is applied to the right rear wheel **20**c.

(72) Secondly, as the backup control, the command unit **70**r increases the command values of the braking forces for the drive units **60**c, **60**d according to the magnitude of the braking force command value for the drive unit **60**a. In this case, the braking force that should be applied to the right front wheel **20**a is distributed and applied to the right rear wheel **20**c and the left rear wheel **20**d.

(73) Thirdly, as the backup control, the command unit **70**f increases the braking force command value for the drive unit **60**b according to the magnitude of the braking force command value for the drive unit **60**a. Furthermore, as the backup control, the command unit **70**r increases the command values of the braking forces for the drive units **60**c, **60**d according to the magnitude of the braking force command value for the drive unit **60**a. In this case, the braking force that should be applied to the right front wheel **20**a is distributed and applied to the left front wheel **20**b, the right rear wheel **20**c, and the left rear wheel **20**d.

(74) Fourthly, as the backup control, the command unit **70**r increases the braking force command value for the drive unit **60**c according to the magnitude of the braking force command value for the drive unit **60**a. Furthermore, as the backup control, the command unit **70**r increases the braking force command value for the drive unit **60**d according to the magnitude of the braking force command value for the drive unit **60**b. In this case, the braking force that should be applied to the

right front wheel **20**a is applied to the right rear wheel **20**c, and the braking force that should be applied to the left front wheel **20**b is applied to the left rear wheel **20**d. Just as described, in the backup control, the drive of the braking mechanism **30**b by the drive unit **60**b, which is paired with the drive unit **60**a diagnosed as not functioning normally, may be limited. In the above embodiment, the first command unit **71** and the second command unit **72** determine the transmission mode of the braking force command value on the basis of the diagnostic result pattern. Thereafter, without changing the drive unit **60** as a transmission destination of the braking force command value, the first command unit **71** and the second command unit **72** change the magnitude of the braking force command value to be transmitted according to a fluctuation in the required braking force. Meanwhile, the first command unit **71** and the second command unit **72** may also determine whether the diagnostic result pattern is changed when changing the magnitude of the braking force command value to be transmitted according to the fluctuation in the required braking force. Then, when the diagnostic result pattern is changed, the first command unit **71** and the second command unit **72** may change the command value transmission mode. In other words, in the flowcharts illustrated in FIG. **4** and FIG. **5**, the first command unit **71** and the second command unit **72** may execute the processing in steps S**11** to S**13** between step S**22** and step S**23**. In the case where the first command unit **71** cannot receive the diagnostic result of the drive unit **60** by the second command unit **72** from the second command unit **72**, the first command unit **71** may determine that the abnormality occurs to the second command unit **72**. In this case, similar to the second pattern or the fifth pattern illustrated in FIG. **3**, the first command unit **71** preferably executes the backup control. The braking mechanism **30** may include a wheel cylinder that presses the friction member **32** harder against the rotary body **31** as the hydraulic pressure is increased. In this case, the electric motor **33** may regulate the force that presses the friction member **32** against the rotary body **31** by regulating the hydraulic pressure in the wheel cylinder. The diagnostic unit **80** may have an abnormality detection sensor that detects the abnormality of the drive unit **60**, the command unit **70**, and the communication line. In this case, based on a detection result by the abnormality detection sensor, the diagnostic unit **80** may diagnose whether each of the drive unit **60**, the command unit **70**, and the communication line functions normally. In the vehicle **10**, the number of the wheels **20** may not be four. For example, the number of the wheels **20** may be two or six. The drive unit **60** is not limited to one that includes the CPU and ROM and executes software processing. For example, a dedicated hardware circuit may be provided for hardware processing on at least some of those subjected to the software processing in each of the above embodiments. An example of the dedicated hardware circuit is an ASIC. ASIC stands for "Application Specific Integrated Circuit". That is, the drive unit **60** only needs to have any of the following configurations (a) to (c).

(75) (a) A processor that executes all of the above processing according to a program and a program storage device such as ROM for storing the program are provided.

(76) (b) A processor and program storage device that executes some of the above processing according to a program and a dedicated hardware circuit that executes rest of the processing are provided.

(77) (c) A dedicated hardware circuit that executes all of the above processing is provided. Here, the number of a software execution device including the processor and the program storage device and the number of the dedicated hardware circuit may be plural. The command unit **70** only needs to have any of the configurations (a) to (c).

Claims

1. A braking control device for a vehicle, the braking control device being applied to a vehicle including: a first braking mechanism that applies a braking force to a first wheel; and a second braking mechanism that applies a braking force to a second wheel, the braking control device for a

vehicle comprising: a first drive unit that drives the first braking mechanism according to a first command value and thereby applies the braking force to the first wheel, the first command value being a braking force command value to be applied to the first wheel; a second drive unit that drives the second braking mechanism according to a second command value and thereby applies the braking force to the second wheel, the second command value being a braking force command value to be applied to the second wheel; a first command unit that derives the first command value and the second command value on the basis of a braking request as a request for the braking force on the vehicle, can transmit the first command value to the first drive unit, and can transmit the second command value to the second drive unit; a second command unit that derives the first command value and the second command value on the basis of the braking request, can transmit the first command value to the first drive unit, and can transmit the second command value to the second drive unit; and a diagnostic unit that diagnoses whether the braking control device functions normally, wherein in the case where the diagnostic unit diagnoses that the braking control device functions normally, the first command unit transmits the first command value to the first drive unit, the first drive unit drives the first braking mechanism according to the first command value transmitted by the first command unit, the second command unit transmits the second command value to the second drive unit, and the second drive unit drives the second braking mechanism according to the second command value transmitted by the second command unit, and in the case where the diagnostic unit diagnoses that the braking control device does not function normally, at least one of the first command unit and the second command unit executes backup control for compensating for a shortage of the braking force of the vehicle for the braking request, which is caused by the braking control device not functioning normally.

2. The braking control device for a vehicle according to claim 1, wherein in the case where the diagnostic unit diagnoses that the first drive unit does not function normally, as the backup control, the second command unit transmits, to the second drive unit, the second command value that is increased according to a magnitude of the first command value.

3. The braking control device for a vehicle according to claim 1, wherein the diagnostic unit includes: a first diagnostic unit that is provided to the first command unit, diagnoses whether the first drive unit functions normally, and diagnoses whether the second drive unit functions normally; and a second diagnostic unit that is provided to the second command unit, diagnoses whether the first drive unit functions normally, and diagnoses whether the second drive unit functions normally, in the case where the first diagnostic unit diagnoses that the first drive unit functions normally, the second command unit does not transmit the first command value to the first drive unit, and in the case where the first diagnostic unit diagnoses that the first drive unit does not function normally, and the second diagnostic unit diagnoses that the first drive unit functions normally, as the backup control, the second command unit transmits the first command value to the first drive unit.

4. The braking control device for a vehicle according to claim 1, wherein in the case where the diagnostic unit diagnoses that the first command unit functions normally, the first drive unit does not accept the first command value transmitted by the second command unit, and drives the first braking mechanism according to the first command value transmitted by the first command unit.

5. The braking control device for a vehicle according to claim 1, wherein the first command unit and the second command unit are mounted to a command control unit, and the first drive unit and the second drive unit are mounted to a different unit from the command control unit.

6. The braking control device for a vehicle according to claim 2, wherein in the case where the diagnostic unit diagnoses that the first command unit functions normally, the first drive unit does not accept the first command value transmitted by the second command unit, and drives the first braking mechanism according to the first command value transmitted by the first command unit.

7. The braking control device for a vehicle according to claim 3, wherein in the case where the diagnostic unit diagnoses that the first command unit functions normally, the first drive unit does not accept the first command value transmitted by the second command unit, and drives the first

braking mechanism according to the first command value transmitted by the first command unit.

8. The braking control device for a vehicle according to claim 2, wherein the first command unit and the second command unit are mounted to a command control unit, and the first drive unit and the second drive unit are mounted to a different unit from the command control unit.

9. The braking control device for a vehicle according to claim 3, wherein the first command unit and the second command unit are mounted to a command control unit, and the first drive unit and the second drive unit are mounted to a different unit from the command control unit.

10. The braking control device for a vehicle according to claim 4, wherein the first command unit and the second command unit are mounted to a command control unit, and the first drive unit and the second drive unit are mounted to a different unit from the command control unit.