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Occupant protection apparatus

Abstract

An occupant protection apparatus to be applied to a vehicle includes a contact detector, a control processor, and a lifting mechanism. The contact detector detects frontal contact of the vehicle. The control processor includes a contact determination unit determining whether the frontal contact of the vehicle is underride contact based on a result of detecting by the contact detector. The lifting mechanism includes a lifting member and a lifting driver. The lifting member is disposed below a rear end part of a hood in a downward direction of the vehicle. The hood is disposed on a frontal part of the vehicle. The lifting driver transmits a driving force to the lifting member. When the contact determination unit determines that the frontal contact is the underride contact, the rear end part of the hood is lifted by the lifting mechanism.

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References Cited

FOREIGN PATENT DOCUMENTS

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102017209061	12/2017	DE	B60R 21/0134
2009-090816	12/2008	JP	N/A

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) The present application claims priority from Japanese Patent Application No. 2022-084886 filed on May 25, 2022, the entire contents of which are hereby incorporated by reference.

BACKGROUND

(2) The disclosure relates to an occupant protection apparatus.

(3) Frontal contact of a vehicle includes underride contact. Upon underride contact, a vehicle slides underneath a contact body. For example, a collision determination device disclosed in Japanese Unexamined Patent Application Publication No. 2009-90816 determines whether frontal contact of a vehicle is underride contact. When determining that the frontal contact is underride contact, the collision determination device operates a passenger protection device such as a seatbelt device at an appropriate timing.

SUMMARY

(4) An aspect of the disclosure provides an occupant protection apparatus to be applied to a vehicle. The occupant protection apparatus includes a contact detector, a control processor, and a lifting mechanism. The contact detector is configured to detect frontal contact of the vehicle. The control processor includes a contact determination unit configured to determine whether the frontal contact of the vehicle is underride contact based on a result of detecting by the contact detector. The lifting mechanism includes a lifting member and a lifting driver. The lifting member is disposed below a rear end part of a hood in a downward direction of the vehicle. The hood is disposed on a frontal

part of the vehicle. The lifting driver is configured to transmit a driving force to the lifting member. When the contact determination unit determines that the frontal contact is the underride contact, the rear end part of the hood is lifted by the lifting mechanism.
(5) An aspect of the disclosure provides an occupant protection apparatus to be applied to a vehicle. The occupant protection apparatus includes circuitry and a lifting mechanism. The circuitry is configured to detect frontal contact of the vehicle and determine whether the frontal contact of the vehicle is underride contact based on a result of detecting. The lifting mechanism includes a lifting member and a lifting driver. The lifting member is disposed below a rear end part of a hood in a downward direction of the vehicle. The hood is disposed on a frontal part of the vehicle. The lifting driver is configured to transmit a driving force to the lifting member. When the circuitry determines that the frontal contact is the underride contact, the rear end part of the hood is lifted by the lifting mechanism.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and, together with the specification, serve to explain the principles of the disclosure.
(2) FIG. **1** is a schematic left side view of a frontal part of a vehicle to which an occupant protection apparatus according to one example embodiment is applied.
(3) FIG. **2** is a schematic plan view of the frontal part of the vehicle illustrated in FIG. **1**.
(4) FIG. **3** is an enlarged side view of a lifting mechanism and an anchor mechanism illustrated in FIG. **1**.
(5) FIG. **4** is a side view of a lifter of the lifting mechanism illustrated in FIG. **1** that is raised to a first lifted position.
(6) FIG. **5** is a side view of the lifter of the lifting mechanism illustrated in FIG. **1** that is raised to a second lifted position and an anchor of the anchor mechanism illustrated in FIG. **1** that is lowered to a ground position.
DETAILED DESCRIPTION
(7) Upon underride contact, a vehicle slides underneath a contact body. A lap amount between the vehicle and the contact body is thus relatively small upon the underride contact. This can hinder contact energy generated upon the contact from being sufficiently absorbed, lowering performance to protect an occupant in the vehicle. It is therefore desired for a vehicle to have a structure that makes it possible to achieve superior performance to protect an occupant in the vehicle upon underride contact.
(8) It is desirable to provide an occupant protection apparatus that makes it possible to achieve superior performance to protect an occupant in a vehicle upon underride contact.
(9) In the following, some example embodiments of the disclosure are described in detail with reference to the accompanying drawings. Note that the following description is directed to illustrative examples of the disclosure and not to be construed as limiting to the disclosure. Factors including, without limitation, numerical values, shapes, materials, components, positions of the components, and how the components are coupled to each other are illustrative only and not to be construed as limiting to the disclosure. Further, elements in the following example embodiments which are not recited in a most-generic independent claim of the disclosure are optional and may be provided on an as-needed basis. The drawings are schematic and are not intended to be drawn to scale. Throughout the present specification and the drawings, elements having substantially the same function and configuration are denoted with the same reference numerals to avoid any redundant description. In addition, elements that are not directly related to any embodiment of the

disclosure are unillustrated in the drawings.

(10) An occupant protection apparatus **10** according to an example embodiment will now be described with reference to the accompanying drawings. Note that, in the drawings, an arrow UP indicates an upward direction of a vehicle (an automobile) V to which the occupant protection apparatus **10** is applied, an arrow FR indicates a frontward direction of the vehicle V, and an arrow RH indicates a righthand direction (one vehicle-width direction) of the vehicle V. Hereinafter, descriptions of directions are made based on the upward and downward directions (also referred to as a vertical direction), the frontward and rearward directions (also referred to as a longitudinal direction), and the right-hand and left-hand directions (also referred to as a vehicle-width direction) of the vehicle V unless otherwise stated.

(11) As illustrated in FIGS. **1** to **5**, the occupant protection apparatus **10** may include a pair of right and left lifting mechanisms **20**, a pair of right and left anchor mechanisms **40**, and a pair of right and left sub-lifting actuators **60**. The lifting mechanisms **20** are configured to lift a rear end part of a hood **80** disposed on a frontal part of the vehicle V. The anchor mechanisms **40** may be configured to project from an underfloor **90** of the vehicle V in the downward direction and come into contact with the ground GR (i.e., to be lowered to a grounded position). The sub-lifting actuators **60** may be configured to lift a longitudinally intermediate part of the hood **80**. In the broad sense, the sub-lifting actuators **60** may serve as sub-lifting mechanisms. The occupant protection apparatus **10** further includes an electronic control unit (ECU) **70**. The ECU **70** may control operations of the lifting mechanisms **20**, the anchor mechanisms **40**, and the sub-lifting actuators **60**. In one embodiment, the ECU **70** may serve as a “control processor”. When the lifting mechanisms **20** and the sub-lifting actuators **60** are operated, the rear end part of the hood **80** may be lifted by the lifting mechanisms **20** and the sub-lifting actuators so that the head of an occupant P is hidden behind (covered with) the hood **80** as seen from in front of the vehicle V (see FIG. **5**). In the following, the hood **80** is described in detail first, following which components of the occupant protection apparatus **10** are described in detail.

(12) <Hood **80**>

(13) The hood **80** may have a substantially rectangular panel-like shape having a thickness in the vertical direction. The hood **80** may be disposed on the frontal part of the vehicle V so as to close an engine room **91** from above. The hood **80** may be provided with a pair of hood hinges **82** disposed below respective vehicle-width ends of the rear end part of the hood **80**. The hood hinges **82** may each include a hinge base **82**A and a hinge arm **82**B. The hinge base **82**A may have a substantially elongated plate-like shape having a thickness in the vertical direction and extending in the longitudinal direction. The hinge base **82**A may be disposed above a non-illustrated cowl constituting a framework of the vehicle V, and may be fastened and fixed to the cowl. The hinge arm **82**B may be disposed substantially in parallel to the hood **80** between the hinge base **82**A and the rear end part of the hood **80**, and may be fastened and fixed to the hood **80**. A rear end part of the hinge arm **82**B may be coupled to a rear end part of the hinge base **82**A so as to be rotatable about an axis extending in the vehicle-width direction. The rear end part of the hood **80** may be thereby coupled to the body of the vehicle V with the hood hinges **82** so as to be rotatable around an axis extending in the vehicle width direction. A striker **84** may be provided on a vehicle-width intermediate part of a frontal end part of the hood **80**. The striker **84** may project in the downward direction as illustrated in FIG. **1**, and a lower end of the striker **84** may be locked with a hood lock device **86** fixed to the body of the vehicle V. The hood **80** may be thereby kept at a closed position so as to close the engine room **91**.

(14) <Lifting Mechanism **20**>

(15) The lifting mechanisms **20** may be disposed below the respective hood hinges **82**. The lifting mechanisms **20** may each include a lifter supporting member **21**, a lifter **22**, and a lifting driver **24**. In the broad sense, the lifter supporting member **21** may serve as a lifting supporting member. In one embodiment, the lifter may serve as a “lifting member”. The lifter supporting member **21** may

have a pillar shape extending in a substantially vertical direction. The lifter supporting member **21** may be disposed inside a front pillar **93** of the vehicle V and fixed to the front pillar **93**. The lifter supporting member **21** may be curved into a substantially arc-shape that protrudes in the rearward direction in side view. For example, the lifter supporting member **21** may be curved into an arc-shape the center of which is located at a lower end of the striker **84** in side view.
(16) The lifter **22** may have a substantially bottomed cylindrical shape that opens in the downward direction. Like the lifter supporting member **21**, the lifter **22** may be curved into a substantially arc-shape that protrudes in the rearward direction in side view. The lifter supporting member **21** may extend inside the lifter **22**. The lifter **22** may be coupled to the lifter supporting member **21** so as to be movable relative to the lifter supporting member **21** in the vertical direction (i.e., along a longitudinal length of the lifter supporting member **21**) and so as not to be movable relative to the lifter supporting member **21** in a circumferential direction of the lifter supporting member **21**. For example, when the lifting mechanism **20** is not operated, the lifter **22** may be located at an initial position as illustrated in FIGS. **1** and **3**. When the lifting mechanism **20** is operated, the lifter **22** may be located at a first lifted position as illustrated in FIG. **4** or a second lifted position as illustrated in FIG. **5**. Note that the first lifted position may be above the initial position, and the second lifted position may be above the first lifted position.
(17) An upper end of the lifter **22** may be disposed below the hinge base **82**A and coupled to the hinge base **82**A with a ball joint **23**. The lifter **22** may thus be coupled to the rear end part of the hood **80** with the hood hinge **82** and the ball joint **23**. When the lifting mechanism **20** is operated, the fixed state of the hinge base **82**A to the body of the vehicle V may be released by a lifting force applied from the lifter **22** to the hinge base **82**A, so that the rear end part of the hood **80** is lifted together with the lifter **22** to a position corresponding to the first lifted position of the lifter **22** or a position corresponding to the second lifted position of the lifter **22**.
(18) When the lifter **22** is lifted to the second lifted position, the rear end part of the hood **80** may be located at a vertical position where the rear end part of the hood overlaps with the head of the occupant P, as illustrated in FIG. **5**. Accordingly, when the lifter **22** is lifted to the second lifted position, the upper body of the occupant P may be hidden behind the hood **80** in front view. In the present example embodiment, when the lifter **22** is lifted to the second lifted position, the rear end part of the hood **80** may be lifted to a height substantially the same as that of an upper end of a windshield glass **94** of the vehicle V so that substantially the entire of the windshield glass **94** is hidden behind the hood **80** in front view. Note that, in the present example embodiment, the position of the head of the occupant P may be assumed to be the position of the head of a crash-test dummy seated in the driver's seat of the vehicle V. The crash-test dummy may be a human dummy representing a 50th percentile American male (AM50).
(19) As to be described in detail later, when the lifter **22** is lifted to the first lifted position, the rear end part of the hood **80** may be located at a predetermined height to receive the head of a person (pedestrian) falling onto the hood **80**. That is, the height of the hood **80** at the position corresponding to the first lifted position of the lifter **22** may be determined to secure the performance to protect a person (pedestrian) falling onto the hood **80**.
(20) As illustrated in FIG. **3**, the lifting driver **24** may include a lifting actuator and a driving power transmitter **30**. The lifting actuator **25** may include a pipe **26** having an elongated shape. The pipe **26** may be disposed in front of the lifter **22** and fixed to the body of the vehicle V. A micro-gas generator **27** (hereinafter referred to as a MGG **27**) may be provided at one end of the pipe **26**. In the broad sense, the MGG **27** may serve as a gas generator. When the MGG **27** is operated, gas generated by the MGG **27** may be supplied to inside the pipe **26**. The MGG **27** may be a two-stage gas generator configured to switch the level of a gas output between two levels, i.e., a low output level and a high output level. The MGG **27** may include two squibs, for example. When the MGG **27** is operated at the low output level, one of the squibs may be activated to burn an ignition agent. When the MGG **27** is operated at the high output level, the two squibs are both activated to burn

the ignition agent. The MGG **27** may be electrically coupled to the ECU **70** to be described later so that an operation of the MGG **27** is controlled by the ECU **70**.
(21) A piston **28** having a columnar shape may be disposed inside the pipe **26** in a movable manner. The piston **28** may be disposed closer to the other end of the pipe **26** than the MGG **27** is. Further, a plurality of balls **29** may be disposed inside the pipe **26** in a movable manner. The balls **29** may be disposed closer to the other end of the pipe **26** than the piston **28** is. Accordingly, when the gas generated by the MGG **27** is supplied to inside the pipe **26**, the piston **28** may be moved toward the other end of the pipe **26** by a gas pressure inside the pipe **26**, and may push the balls **29**. The balls **29** and the piston **28** may be thereby moved toward the other end of the pipe **26**.
(22) The driving power transmitter **30** may be disposed between an upper end part of the lifter **22** and the pipe **26**. The driving power transmitter **30** may include a pinion **31**, a transmission gear **32**, and a rack **33** that is provided on the lifter **22**. The pinion **31** may be a two-stage gear that includes a first pinion gear **31**A and a second pinion gear **31**B. A part of the first pinion gear **31**A may be disposed inside the pipe **26** such that the first pinion gear **31**A engages with the balls **29**. The second pinion gear **31**B and the transmission gear **32** may be in mesh, and the transmission gear **32** may have a larger diameter than the second pinion gear **31**B. The rack **33** may extend on an outer circumference of the lifter **22** along a longitudinal length of the lifter **22**, and the transmission gear **32** and the rack **33** may be in mesh. Accordingly, when the MGG **27** is operated to move the balls **29** toward the other end of the pipe **26**, the pinion **31** and the transmission gear **32** may be rotated to raise the lifter **22** from the initial position. For example, the lifter **22** may be raised to the first lifted position when the MGG **27** is operated at the low output level, and to the second lifted position when the MGG **27** is operated at the high output level. Note that the pinion **31** and the transmission gear **32** may be rotatably supported by a non-illustrated gear holder fixed to the body of the vehicle V.
(23) The lifting driver **24** may further include a lock mechanism **34**. The lock mechanism **34** may hold the lifter **22** raised to the first lifted position or the second lifted position. The lock mechanism **34** may include a lock member **35** that is rotatably coupled to a lower circumferential end of the lifter **22**. The lock member may be configured to engage with any of lock grooves **36** provided on the lifter supporting member **21**. When the lock member **35** engages with any of the lock grooves **36**, the lifter **22** is prevented from moving in the downward direction. The lock grooves **36** may be provided at respective positions corresponding to the initial position, the first lifted position, and the second lifted position of the lifter **22**. When the lifter **22** is raised to the first lifted position or the second lifted position, the lock member **35** may engage with the corresponding lock groove **36**. The lock member **35** may be urged by a non-illustrated urging member in a direction in which the lock member **35** is to engage with the lock groove **36**. While the lifter **22** is being raised, the lock member **35** may be caused to slide on the outer circumference of the lifter supporting member **21** by an urging force of the urging member.
(24) <Anchor Mechanism **40**>
(25) As illustrated in FIGS. **1** and **3**, the anchor mechanisms **40** may be disposed below the respective lifting mechanisms **20**. The anchor mechanisms **40** may each include an anchor supporting member **41**, an anchor member **42**, and an anchor driver **44**. The anchor supporting member **41** may have a pillar shape extending in the vertical direction. The anchor supporting member **41** may be disposed inside the front pillar **93** of the vehicle V and fixed to the front pillar **93**. An upper end of the anchor supporting member **41** may be coupled to a lower end of the lifter supporting member **21** of the lifting mechanism **20**. That is, in the present example embodiment, the anchor supporting member **41** and the lifter supporting member **21** may be integrated with each other into a single member. Alternatively, the anchor supporting member **41** and the lifter supporting member **21** may be members separate from each other.
(26) The anchor member **42** may have a substantially bottomed cylindrical shape that opens in the upward direction. The anchor supporting member **41** may extend inside the anchor member **42**. The

anchor member **42** may be coupled to the anchor supporting member **41** so as to be movable relative to the anchor supporting member **41** in the vertical direction (i.e., along a longitudinal length of the anchor supporting member **41**) and so as not to be movable relative to the anchor supporting member **41** in a circumferential direction of the anchor supporting member **41**. For example, when the anchor mechanism **40** is not operated, the anchor member **42** may be located at an initial position as illustrated in FIGS. **1** and **3**. When the anchor member **42** is located at the initial position, the anchor member **42** may not project from the underfloor **90** of the vehicle V in the downward direction. When the anchor mechanism **40** is operated, the anchor member **42** may be lowered from the initial position to the grounded position as illustrated in FIG. **5**. When the anchor mechanism **40** is lowered to the grounded position, a lower end of the anchor member **42** may come into contact with the ground GR, that is, the lower end of the anchor member **42** may be grounded. Accordingly, the anchor mechanism **40** may apply a reaction force in the upward direction from the ground GR to the vehicle V. Note that the anchor member **42** located at the initial position may be held by a non-illustrated holding member.

(27) The anchor driver **44** may have a configuration similar to that of the lifting driver **24** of the lifting mechanism **20**. For example, the anchor driver **44** may include an anchor actuator **45** and a driving power transmitter **50**. The anchor actuator **45** may include a pipe **46** having an elongated shape. The pipe **46** may be disposed in front of the anchor member **42** and fixed to the body of the vehicle V. A micro-gas generator **47** (hereinafter referred to as a MGG **47**) may be provided at one end of the pipe **46**. In the broad sense, the MGG **47** may serve as a gas generator. When the MGG **47** is operated, gas generated by the MGG **47** may be supplied to inside the pipe **46**. Unlike the MGG **27** of the lifting mechanism **20**, the MGG **47** may be a one-stage gas generator. The MGG **47** may be electrically coupled to the ECU **70** to be described later so that an operation of the MGG **47** is controlled by the ECU **70**.

(28) A piston **48** having a cylindrical shape may be disposed inside the pipe **46** in a movable manner. The piston **48** may be disposed closer to the other end of the pipe **46** than the MGG **47** is. Further, a plurality of balls **49** may be disposed inside the pipe **46** in a movable manner. The balls **49** may be disposed closer to the other end of the pipe **46** than the piston **48** is.

(29) The driving power transmitter **50** may include a pinion **51**, a transmission gear **52**, and a rack **53** that is provided on the anchor member **42**. The pinion **51** may be a two-stage gear that includes a first pinion gear **51**A and a second pinion gear **51**B. The first pinion gear **51**A may engage with the balls **49**. The second pinion gear **51**B and the transmission gear **52** may be in mesh, and the transmission gear **52** may have a larger diameter than the second pinion gear **51**B. The rack **53** may extend on an outer circumference of the anchor member **42** in the vertical direction, and the transmission gear **52** and the rack **53** may be in mesh. Accordingly, when the MGG **47** is operated to move the balls **49** toward the other end of the pipe **46**, the pinion **51** and the transmission gear **52** may be rotated to lower the anchor member **42** from the initial position.

(30) The anchor driver **44** may further include a lock mechanism **54**. The lock mechanism **54** may prevent the anchor member **42** lowered to the grounded position from moving in the upward direction. Like the lock mechanism **34**, the lock mechanism **54** may include a lock member **55** that is rotatably coupled to an upper circumferential end of the anchor member **42**. The lock member **55** may be configured to engage with any of lock grooves **56** provided on the anchor supporting member **41**. When the lock member **55** engages with any of the lock grooves **56**, the anchor member **42** is prevented from moving in the upward direction. The lock grooves **56** may be provided at respective positions corresponding to the initial position and the grounded position of the anchor member **42**. When the anchor member **42** is lowered to the grounded position, the lock member **55** may engage with the corresponding lock groove **56**. The anchor member **42** may be urged by a non-illustrated urging member in a direction in which the anchor member **42** is to engage with the lock groove **56**. While the anchor member **42** is being lowered, the lock member **55** may be caused to slide on the outer circumference of the anchor supporting member **41** by an

urging force of the urging member.
(31) <Sub-Lifting Actuator **60**>
(32) As illustrated in FIG. **1**, the sub-lifting actuators **60** may be disposed below the respective vehicle-width ends of the longitudinally intermediate part of the hood **80**. The sub-lifting actuators **60** may each include a cylinder **61**, a micro-gas generator **62** (hereinafter referred to as a MGG **62**), and a piston rod **63**. In the broad sense, the MGG **62** may serve as a gas generator.
(33) The cylinder **61** may have a cylindrical shape having an axis along a substantially vertical direction. The cylinder **61** may be fixed to the body of the vehicle V. For example, an upper part of the cylinder **61** may slightly incline in the forward direction in side view. The MGG **62** may be fit in a lower end of the cylinder **61**. When the MGG **62** is operated, gas generated by the MGG **62** may be supplied into the cylinder **61**. The MGG **62** may be electrically coupled to the ECU **70** to be described later so that an operation of the MGG **62** is controlled by the ECU **70**.
(34) The piston rod **63** may extend along the axis of the cylinder **61**. A lower part of the piston rod **63** may be disposed inside the cylinder **61** in a movable manner. An upper end of the piston rod **63** may be disposed close to a lower side of the hood **80**. As to be described in detail later, the sub-lifting actuator **60** may be operated together with the lifting mechanism **20** to lift the hood **80** to the position corresponding to the second lifted position of the lifter **22** in cooperation with the lifting mechanism **20**.
(35) <ECU **70**>
(36) As illustrated in FIG. **2**, the ECU **70** may be electrically coupled to the MGGs **27**, **47**, and **62** described above so that operations of the MGGs **27**, **47**, and **62** are controlled by the ECU **70**. Further, a first contact detection sensor **71**, second contact detection sensors **72**, and third contact detection sensors **73** may be electrically coupled to the ECU **70**. In one embodiment, the first contact detection sensor **71**, the second contact detection sensors **72**, and the third contact detection sensors **73** may each serve as a “contact detector”. The ECU **70** may determine whether to operate the MGGs **27**, **47**, and **62** based on detection signals outputted from these sensors.
(37) The first contact detection sensor **71** may be disposed in front of a bumper beam **96** provided on a frontal end part of the vehicle V. The first contact detection sensor **71** may include a pressure tube **71**A and pressure sensors **71**B. The pressure tube **71**A may be an elongated hollow tube extending in the vehicle-width direction. The pressure sensors **71**B may be disposed at respective longitudinal ends of the pressure tube **71**A. When a contact body comes into contact with the frontal end part of the vehicle V, the pressure tube **71**A may be compressed, changing the pressure inside the pressure tube **71**A. The pressure sensor **71**B may then output a signal based on the change in the pressure inside the pressure tube **71**A to the ECU
(38) The second contact detection sensors **72** may be disposed on respective frontal end portions of right and left front side frames **97** in pair. The pair of front side frames may be disposed on the frontal part of the vehicle V and extend in the longitudinal direction of the vehicle V. The second contact detection sensors **72** may each serve as an acceleration sensor that outputs a signal based an acceleration rate inputted to the vehicle V to the ECU **70**.
(39) The third contact detection sensors **73** may include a stereo camera **73**A and millimeter-wave radars **73**B. The stereo camera **73**A may be disposed on an upper part of the windshield glass **94** at a position near a vehicle-width intermediate position. The stereo camera **73**A may capture an image of an environment in front of the vehicle V to detect a contact body in contact with the vehicle V, and may output measurement data including data on the image of the contact body to the ECU **70**. The stereo camera **73**A may measure, for example, a distance to the detected contact body and and a relative speed between the vehicle V and the contact body, and may output the measurement data to the ECU **70**. The millimeter-wave radars **73**B may be disposed on a bumper grill **95** that is disposed on the frontal end part of the vehicle V. The millimeter-wave radars **73**B may each measure a position of the contact body, a distance to the contact body, and a speed of the contact body, and may output the measured data to the ECU **70**.

(40) The ECU **70** may include a contact determination unit **70**A. The contact determination unit **70**A may determine the type of frontal contact of the vehicle V based on a result of detection by the third contact detection sensors **73**. For example, the contact determination unit **70**A may determine whether the frontal contact of the vehicle V is underride contact, that is, whether the vehicle V has slid underneath the contact body. If it is determined by the contact determination unit **70**A that the frontal contact of the vehicle V is underride contact, the ECU **70** may cause the MGGs **27** of the lifting mechanisms **20** to operate at the high output level, and may cause the MGGs **62** of the sub-lifting actuators **60** to operate. Further, if it is determined that the frontal contact of the vehicle V is underride contact, the ECU **70** may cause one or both of the MGG **47** of the right anchor mechanism **40** and the MGG **47** of the left anchor mechanism **40** to operate based on results of detection outputted from the second contact detection sensors **72** after the lifting mechanisms and the sub-lifting actuators **60** are operated (i.e., after an elapse of a predetermined time from the start of operations of the MGGs **27** and **62**).
(41) In contrast, if it is determined by the contact determination unit **70**A that the frontal contact of the vehicle V is not underride contact, the contact determination unit **70**A may determine whether the contact body in contact with the vehicle V is a person (pedestrian) based on the results of detection outputted from the first contact detection sensor **71** and the third contact detection sensors **73**. If it is determined that the contact body in contact with the vehicle V is a person, the ECU may cause the MGGs **27** to operate at the low output level to thereby cause the lifting mechanisms **20** to operate, that is, the ECU **70** may keep the sub-lifting actuators **60** and the anchor mechanisms **40** in non-operational states. In contrast, if it is determined that the contact body in contact with the vehicle V is a contact body other than a person, the ECU **70** may keep the MGGs **27**, **47**, and **62** in non-operational states, that is, the ECU **70** may keep the lifting mechanisms **20**, the anchor mechanisms **40**, and the sub-lifting actuators **60** in non-operational states.
Workings and Effects
(42) Now, workings and effects of the present example embodiment are described.
(43) While the lifting mechanisms **20** and the sub-lifting actuators **60** are in the non-operational states, the hood **80** may be located at the closed position so as to close the engine room **91**, as illustrated in FIG. **1**. While the anchor mechanisms are in the non-operational states, the anchor members **42** may be located so as not to project from the underfloor **90** of the vehicle V in the downward direction. Thereafter, if the contact determination unit **70**A of the ECU **70** detects frontal contact of the vehicle V other than underride contact based on the output signals from the first to third contact detection sensors **71** to **73** and determines that the contact body making frontal contact with the vehicle V is a person, the ECU **70** may cause the MGGs **27** of the lifting mechanisms **20** to operate at the low output level.
(44) The lifting drivers **24** of the lifting mechanisms **20** may be thereby operated to raise the lifters **22** to the first lifted position as illustrated in FIG. **4**. For example, gas may be supplied from the MGG **27** to inside the pipe **26**, and the piston **28** may be moved toward the other end of the pipe **26** by the gas pressure inside the pipe **26**. The piston **28** may push the balls **29** to thereby move together with the balls **29** toward the other end of the pipe **26**. This may rotate the pinion **31** and the transmission gear **32** of the lifting mechanism **20**, raising the rack **33** in mesh with the transmission gear **32**. The lifter **22** may be thereby lifted from the initial position to the first lifted position, and the rear end part of the hood **80** may be lifted to the position corresponding to the first lifted position of the lifter **22**. For example, while being lifted, the rear end part of the hood **80** may rotate around the lower end of the striker **84** locked with the hood lock device **86** provided on the frontal end part of the hood **80** in side view. As a result, the person (pedestrian) falling onto the hood **80** upon the frontal contact may be received by the hood **80** lifted to the position corresponding to the first lifted position of the lifter **22** with a space formed below the rear end part of the hood **80**.
(45) In contrast, if the contact determination unit **70**A of the ECU **70** detects underride contact of the vehicle V based on the output signals from the first to third contact detection sensors **71** to **73**,

the ECU **70** may cause the MGGs **27** of the lifting mechanisms **20** to operate at the high output level and may cause the MGGs **62** of the sub-lifting actuators **60** to operate.

(46) The lifting drivers **24** of the lifting mechanisms **20** may be thereby operated to raise the lifters **22**, as in the manner described above. At this time, the MGGs **27** may be operated at the high output level, and the lifters **22** may thus be lifted to the second lifted position as illustrated in FIG. **5**. Further, gas generated by the MGG **62** may be supplied to the cylinder **61** of the sub-lifting actuator **60**, and the piston rod **63** may be raised by the gas pressure inside the cylinder **61**, lifting the longitudinally intermediate part of the hood **80**. Accordingly, the rear end part of the hood **80** may be lifted to the position corresponding to the second lifted position of the lifter **22** by the lifting mechanisms **20** and the sub-lifting actuators **60** so that the windshield glass **94** is hidden behind the hood **80** in front view. The contact body (e.g., a contact body C illustrated in FIG. **5**) may be received by the hood **80** lifted to the position corresponding to the second lifted position of the lifter **22** to absorb contact energy applied to the vehicle V.

(47) The contact determination unit **70**A of the ECU **70** may determine the position of contact between the contact body C and the vehicle V in the vehicle-width direction based on the output signals received from the second contact detection sensors **72**, and may cause, based on the result of the determination, the MGGs **47** of the anchor mechanisms **40** to operate. For example, when the contact body C comes into contact with a right part of the vehicle V, the MGG **47** of the right anchor mechanism **40** may be operated after the MGGs **27** and the MGGs **62** are operated. When the contact body C comes into contact with a left part of the vehicle V, the MGG **47** of the left anchor mechanism **40** may be operated after the MGGs **27** and the MGGs **62** are operated. That is, when the position of contact between the contact body C and the vehicle V is deviated from the vehicle-width intermediate part of the vehicle V, one of the MGGs **47** of the anchor mechanisms closer to the contact position with reference to the vehicle-width intermediate part of the vehicle V may be operated. When the contact body C comes into contact with a substantially intermediate part of the vehicle V in the vehicle-width direction, both of the MGG **47** of the right anchor mechanism **40** and the MGG **47** of the left anchor mechanism **40** may be operated after the MGGs **27** and the MGGs **62** are operated.

(48) The anchor driver **44** of the anchor mechanism **40** may be thereby operated, and the anchor member **42** may be lowered from the initial position to project from the underfloor **90** of the vehicle V. For example, gas may be supplied from the MGG **47** to inside the pipe **46**, and the piston **48** may be moved toward the other end of the pipe **46** by the gas pressure inside the pipe **46**. The piston **48** may push the balls **49** to thereby move together with the balls **49** toward the other end of the pipe **46**. This may rotate the pinion **51** and the transmission gear **52** of the anchor mechanism **40**, lowering the rack **53** in mesh with transmission gear **52**. The anchor member **42** may be thereby lowered from the initial position, bringing the lower end of the anchor member **42** into contact with the ground GR. Accordingly, an reaction force may be applied in the upward direction from the ground GR to the anchor member **42** and the anchor supporting member **41**. The reaction force may be transmitted from the anchor supporting member **41** to the lifter **22** and the lifter supporting member **21** of the lifting mechanism **20**, and may be applied to the contact body C through the hood **80**.

(49) As described above, the occupant protection apparatus **10** includes the lifting mechanisms **20**, and the lifting mechanisms **20** each include the lifter **22** and the lifting driver. The lifter **22** may be coupled to the rear end part of the hood **80**, and the lifting driver **24** is configured to apply a driving force to the lifter **22**. When the contact determination unit **70**A of the ECU **70** determines that the frontal contact of the vehicle V is underride contact, the ECU **70** may cause the lifting driver **24** to operate to raise the lifter **22** to the second lifted position, and the rear end part of the hood **80** may be lifted by the lifter **22**. When the lifter **22** is located at the second lifted position, the rear end part of the hood **80** may be located at the vertical position where the hood **80** overlaps with the head of the occupant P. Accordingly, when the vehicle V makes underride contact by sliding underneath the

contact body C, the hood **80** may serve as a screen (see FIG. **5**). Upon the underride contact, the contact body C is received by the hood **80** lifted to the position corresponding to the second lifted position of the lifter **22**, which prevents the contact body C from entering the cabin of the vehicle V. That is, upon the underride contact, the lap amount between the vehicle V and the contact body C is increased, and the contact energy generated upon the underride contact is absorbed by the hood **80** and the lifting mechanisms **20**. It is therefore possible to improve the performance to protect the occupant P upon underride contact.

(50) According to the occupant protection apparatus **10**, when the contact determination unit **70**A of the ECU **70** determines that the contact body C making frontal contact with the vehicle V is a person (pedestrian), the ECU **70** may cause the MGGs **27** of the lifting mechanisms **20** to operate at the low output level so that the rear end part of the hood **80** is lifted by the lifters **22** to the position corresponding to the first lifted position of the lifter **22**. In contrast, when the contact determination unit **70**A of the ECU **70** determines that the frontal contact of the vehicle V is underride contact, the ECU **70** may cause the MGGs **27** of the lifting mechanisms **20** to operate at the high output level so that the rear end part of the hood **80** is lifted by the lifters **22** to the position corresponding to the second lifted position of the lifter **22**, as described above. In other words, the occupant protection apparatus **10** may be configured to lift the rear end part of the hood **80** to the two different lifted positions. This allows the hood **80** to serve differently depending on the types of the frontal contact. For example, upon underride contact, the hood may serve as a protection member that absorbs the contact energy generated upon the underride contact to protect the occupant P, whereas upon frontal contact with a person (pedestrian), the hood **80** may serve as a protection member that absorbs the contact energy generated upon the frontal contact to protect the person (pedestrian) falling onto the hood **80**. Accordingly, upon frontal contact of the vehicle V with a person (pedestrian), it is possible to protect the person falling onto the hood **80** using the occupant protection apparatus **10** that absorbs the contact energy generated upon the underride contact.

(51) The anchor mechanisms **40** may be disposed below the respective lifting mechanisms **20**. The anchor mechanisms **40** may each include the anchor member **42** and the anchor driver **44** that applies a driving force to the anchor member **42**. Upon underride contact, the anchor driver **44** may be operated by the ECU **70** to cause the anchor member **42** to project from the underfloor **90** of the vehicle V in the downward direction and come into contact with the ground GR. Accordingly, a reaction force may be applied in the upward direction from the ground GR to the anchor mechanism **40**. The reaction force may be transmitted to the lifting mechanism **20** and applied to the contact body C through the rear end part of the hood **80**. Further, a contact load applied from the contact body C to the hood **80** may be transmitted from the lifting mechanism **20** and the anchor mechanism **40** to the ground GR. Accordingly, it is possible to effectively improve the performance to protect the occupant P.

(52) After operating the MGGs **27** of the lifting mechanisms **20**, the ECU **70** may cause the MGGs **47** of the anchor mechanisms **40** to operate. Accordingly, it is possible to apply a reaction force from the hood **80** to the contact body C while stabilizing the state of the vehicle V upon underride contact. If the MGG s **47** of the anchor mechanisms **40** are operated before the MGGs **27** of the lifting mechanisms **20** are operated, wheels **98** of the vehicle V can leave the ground GR when the anchor members **42** come into contact with the ground GR. This can bring the vehicle V into an unstable state, making it difficult to apply an effective reaction force from the hood **80** to the contact body C. In contrast, in the present example embodiment, the MGGs **47** of the anchor mechanisms **40** may be operated after the MGGs **27** of the lifting mechanisms **20** are operated. Thus, at an early stage of the underride contact, the hood **80** lifted to the position corresponding to the second lifted position of the lifter **22** may come into contact with the contact body C to thereby apply a reaction force to the contact body C while the vehicle V is supported by the wheels **98**. At a later stage of the underride contact, the anchor mechanisms **40** may increase the reaction force to be applied to the contact body C. Accordingly, it is possible to apply the reaction force from the

hood **80** to the contact body C while stabilizing the state of the vehicle V upon underride contact.

(53) The MGG **47** of the right anchor mechanism **40** may be operated when the contact body C comes into contact with a right part of the vehicle V, whereas the MGG **47** of the left anchor mechanism **40** may be operated when the contact body C comes into contact with a left part of the vehicle V. In other words, when the position of contact between the contact body C and the vehicle V is deviated from the intermediate part of the vehicle V in the vehicle-width direction, one of the MGGs **47** of the anchor mechanisms **40** closer to the position of the contact in the vehicle width direction may be operated. When the contact body C comes into contact with a substantially intermediate part of the vehicle V in the vehicle-width direction, both of the MGG **47** of the right anchor mechanism **40** and the MGG **47** of the left anchor mechanism **40** may be operated. This makes it possible to effectively apply a reaction force to the contact body C. When the position of contact between the contact body C and the vehicle V is deviated from the vehicle-width intermediate part of the vehicle V in the vehicle width direction, a yawing behavior of the vehicle V may be caused by operating one of the MGGs **47** of the anchor mechanisms **40** closer to the contact position. The contact energy applied to the vehicle V may be thereby converted into the yawing behavior of the vehicle V. This suppresses a deformation of the vehicle V upon the underride contact.

(54) Further, the sub-lifting actuators **60** may be disposed below the respective vehicle-width ends of the longitudinally intermediate part of the hood **80**. Upon underride contact, the ECU **70** may cause the sub-lifting actuators **60** to operate so that the hood **80** is lifted to the position corresponding to the second lifted position of the lifter **22** by the piston rods **63** of the sub-lifting actuators **60**. Accordingly, the longitudinally intermediate part of the hood **80** lifted to the position corresponding to the second lifted position of the lifter **22** is supported by the sub-lifting actuators **60** upon the underride contact. This makes it possible to improve the function of supporting the hood **80** upon the underride contact and transmit the contact load applied to the hood **80** upon the contact of the contact body C with the hood **80** to the vehicle body of the vehicle V in a distributed manner.

(55) Further, the lifting driver **24** of the lifting mechanism **20** may include the lifting actuator **25**. The lifting actuator **25** may include the MGG **27** configured to be operated by the ECU **70**. This allows the lifting mechanism **20** to promptly operate to lift the lifter **22** to the first or second lifted position upon underride contact. Further, the lifting driver **24** of the lifting mechanism **20** may include the pinion **31**, the transmission gear **32** in mesh with the second pinion gear **31**B of the pinion **31**, and the rack **33** provided on the lifter **22** and being in mesh with the transmission gear **32**. The transmission gear **32** may have a larger diameter than the second pinion gear **31**B. Accordingly, the driving force of the lifting actuator **25** is amplified and transmitted to the lifter **22**. Accordingly, it is possible to lift the hood appropriately.

(56) Although some embodiments of the disclosure have been described in the foregoing by way of example with reference to the accompanying drawings, the disclosure is by no means limited to the embodiments described above. It should be appreciated that modifications and alterations may be made by persons skilled in the art without departing from the scope as defined by the appended claims. The disclosure is intended to include such modifications and alterations in so far as they fall within the scope of the appended claims or the equivalents thereof. As used herein, the term “collision” may be used interchangeably with the term “contact”.

(57) One or more of the first contact detection sensor **71**, the second contact detection sensors **72**, the third contact detection sensors **73**, and the ECU **70** in FIG. **2** are implementable by circuitry including at least one semiconductor integrated circuit such as at least one processor (e.g., a central processing unit (CPU)), at least one application specific integrated circuit (ASIC), and/or at least one field programmable gate array (FPGA). At least one processor is configurable, by reading instructions from at least one machine readable non-transitory tangible medium, to perform all or a part of functions of the first contact detection sensor **71**, the second contact detection sensors **72**,

the third contact detection sensors **73**, and the ECU **70**. Such a medium may take many forms, including, but not limited to, any type of magnetic medium such as a hard disk, any type of optical medium such as a CD and a DVD, any type of semiconductor memory (i.e., semiconductor circuit) such as a volatile memory and a non-volatile memory. The volatile memory may include a DRAM and a SRAM, and the nonvolatile memory may include a ROM and a NVRAM. The ASIC is an integrated circuit (IC) customized to perform, and the FPGA is an integrated circuit designed to be configured after manufacturing in order to perform, all or a part of the functions of the first contact detection sensor **71**, the second contact detection sensors **72**, the third contact detection sensors **73**, and the ECU **70** in FIG. **2**.

Claims

1. An occupant protection apparatus to be applied to a vehicle, the occupant protection apparatus comprising: a contact detector configured to detect frontal contact of the vehicle; a control processor comprising a contact determination unit configured to determine whether the frontal contact of the vehicle is underride contact based on a result of detecting by the contact detector; a lifting mechanism comprising a lifting member disposed below a rear end part of a hood in a downward direction of the vehicle, the hood being disposed on a frontal part of the vehicle, and a lifting driver configured to transmit a driving force to the lifting member; and an anchor mechanism disposed below the lifting mechanism in the downward direction of the vehicle, the anchor mechanism comprising an anchor member configured to project from an underfloor of the vehicle in the downward direction of the vehicle when being operated, and an anchor driver configured to transmit a driving force to the anchor member, wherein, when the contact determination unit determines that the frontal contact is the underride contact, the rear end part of the hood is lifted by the lifting mechanism, and the anchor driver is operated by the control processor to cause the anchor member to project from the underfloor of the vehicle in the downward direction of the vehicle and come into contact with a ground.
2. The occupant protection apparatus according to claim 1, wherein the lifting mechanism is configured to lift the rear end part of the hood to a position corresponding to an occupant's head position in a vertical direction of the vehicle when viewed from a front side of the vehicle.
3. An occupant protection apparatus to be applied to a vehicle, the occupant protection apparatus comprising: circuitry configured to detect frontal contact of the vehicle and determine whether the frontal contact of the vehicle is underride contact based on a result of detecting; a lifting mechanism comprising a lifting member disposed below a rear end part of a hood in a downward direction of the vehicle, the hood being disposed on a frontal part of the vehicle, and a lifting driver configured to transmit a driving force to the lifting member; and an anchor mechanism disposed below the lifting mechanism in the downward direction of the vehicle, the anchor mechanism comprising an anchor member configured to project from an underfloor of the vehicle in the downward direction of the vehicle when being operated, and an anchor driver configured to transmit a driving force to the anchor member, wherein, when the circuitry determines that the frontal contact is the underride contact, the rear end part of the hood is lifted by the lifting mechanism, and the anchor driver is operated by the circuitry to cause the anchor member to project from the underfloor of the vehicle in the downward direction of the vehicle and come into contact with a ground.