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### Vehicle door device

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#### Abstract

A vehicle door device includes a first link mechanism formed of first and second link arms having a first rotary coupling point with respect to a vehicle body and a second rotary coupling point with respect to a door of a vehicle, and a second link mechanism formed of the first and second link arms provided independently of the first and second link arms forming the first link mechanism. First and second doors respectively supported by the first and second link mechanisms open and close independently in different directions based on operations of the first and second link mechanisms. At least one of the first and second link arms forming the first link mechanism and the first and second link arms forming the second link mechanism is provided with a coupling length variable mechanism that allows a coupling length between the first and second rotary coupling points to vary.

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## Background/Summary

## CROSS REFERENCE TO RELATED APPLICATIONS

(1) This application is based on and claims priority under 35 U.S.C. § 119 to Japanese Patent Application 2021-207143, filed on Dec. 21, 2021, the entire content of which is incorporated herein by reference.

## TECHNICAL FIELD

(2) This disclosure relates to a vehicle door device.

## BACKGROUND DISCUSSION

(3) In the related art, some vehicles have so-called double opening doors that are opened and closed in opposite directions. For example, JP 2021-31907A discloses a vehicle including a front door having a rotary fulcrum at a front edge portion of a door opening, and a rear door having a rotary fulcrum at a rear edge portion of the door opening. In the vehicle, a striker provided at a distal end portion of the rear door and a latch provided at a distal end portion of the front door are engaged with each other, so that the front door and the rear door are restrained at a fully closed position. By using such a double opening door, it is possible to secure a large door opening amount and improve getting-on-and-off performance.

(4) However, a swing door as described above, which is opened and closed about a rotary fulcrum provided on a base end side, has a feature that a distal end side thereof protrudes in an opening direction of the door opening as the door opening amount increases. For this reason, for example, in order to avoid interference with an obstacle located in the opening direction of the door opening, such as a wall located in a vehicle width outer direction or a vehicle stopped adjacent thereto, a situation occurs in which the swing door cannot be largely opened. Also in the related art described above, the door opening amount in an actual use situation may be limited.

## SUMMARY

(5) According to an aspect of this disclosure, a vehicle door device that solves the above problem includes: a first link mechanism formed of first and second link arms having a first rotary coupling point with respect to a vehicle body and a second rotary coupling point with respect to a door of a vehicle; and a second link mechanism formed of the first and second link arms provided independently of the first and second link arms forming the first link mechanism. A first door supported by the first link mechanism and a second door supported by the second link mechanism are disposed side by side in a door opening formed in the vehicle, and thereby open and close independently in different directions based on operations of the first and second link mechanisms. At least one of the first and second link arms forming the first link mechanism and the first and second link arms forming the second link mechanism is provided with a coupling length variable mechanism that allows a coupling length between the first and second rotary coupling points to vary.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:

(2) FIG. 1 is a front view of a front door and a rear door that are provided at a door opening of a vehicle;

(3) FIG. 2 is a front view of the front door and the rear door that are provided at the door opening of the vehicle;

(4) FIG. 3 is a top view of a door device that opens and closes the front door and the rear door of the vehicle;

(5) FIG. 4 is a perspective view of the door device that opens and closes the front door and the rear

door of the vehicle;

(6) FIG. 5 is a plan view of a joint link mechanism constituting a coupling length variable mechanism;

(7) FIG. 6 is a plan view of the joint link mechanism constituting the coupling length variable mechanism;

(8) FIG. 7 is an explanatory view showing an opening and closing trajectory of the front door and the rear door in the vicinity of a fully closed position;

(9) FIG. 8 is a schematic configuration diagram of a door side engagement portion and a vehicle body side engagement portion;

(10) FIG. 9 is a schematic configuration diagram of a door lock system that restrains the front door and the rear door at the fully closed position;

(11) FIG. 10 is a perspective view of the vicinity of a front end portion of the rear door;

(12) FIG. 11 is an external view of a vehicle interior in the vicinity of a front door supported by a link mechanism formed of first and second link arms and a dash panel disposed at a front portion of the vehicle interior;

(13) FIG. 12 is an external view of the vicinity of the front door and the dash panel;

(14) FIG. 13 is an external view of the vicinity of the front door and the dash panel with a partial cross section showing the arrangement of the first and second link arms;

(15) FIG. 14 is an external view of the vehicle interior showing a positional relationship among the front door, a link cover, and the dash panel when the front door is in a fully closed state;

(16) FIG. 15 is an external view of the vicinity of a foot space formed below the dash panel;

(17) FIG. 16 is an explanatory view showing getting-on-and-off performance of the front door that opens toward the front of the vehicle; and

(18) FIG. 17 is an external view of the vicinity of an accommodation recess of the second link arm provided in the front door and a lid member that covers an opening of the accommodation recess.

#### DETAILED DESCRIPTION

(19) Hereinafter, an embodiment of a vehicle door device will be described with reference to the drawings.

(20) As shown in FIGS. 1 to 4, a vehicle 1 according to the present embodiment has a door opening 3 formed in a side surface 2s of a vehicle body 2. In the vehicle 1 according to the present embodiment, the door opening 3 does not have a pillar structure at a central portion in a vehicle front-rear direction (a left-right direction in each drawing), and has a so-called pillarless structure in which a front opening 4 and a rear opening 5 are integrated. The vehicle 1 according to the present embodiment includes a pair of doors 10, 10 provided in the door opening 3. In the vehicle 1 according to the present embodiment, the doors 10, 10 are provided side by side in the vehicle front-rear direction, that is, in an opening width direction of the door opening 3. Further, the doors 10, 10 are supported by the vehicle body 2 via link mechanisms 20, 20 provided independently of each other. Accordingly, in the vehicle 1 according to the present embodiment, based on an operation of the link mechanisms 20, 20, a vehicle door device 30 capable of independently opening and closing the pair of doors 10, 10 provided in the door opening 3 in opposite directions is formed.

(21) That is, in the vehicle 1 according to the present embodiment, the door 10 disposed in the front opening 4 constituting a front portion (a left side in each drawing) of the door opening 3 constitutes a front door 31 of the vehicle 1. The door 10 disposed in the rear opening 5 constituting a rear portion (a right side in each drawing) of the door opening 3 constitutes a rear door 32 of the vehicle 1. Further, in the vehicle door device 30 according to the present embodiment, the front door 31 serves as a first door 41. The link mechanism 20 supporting the first door 41 constitutes a first link mechanism 51. The rear door 32 serves as a second door 42. The link mechanism 20 supporting the second door 42 constitutes a second link mechanism 52.

(22) Specifically, in the vehicle door device 30 according to the present embodiment, each of the

link mechanisms **20**, **20** includes first and second link arms **61**, **62** that are independent from each other. Further, the first and second link arms **61**, **62** each have a first rotary coupling point **X1** with respect to the vehicle body **2** and a second rotary coupling point **X2** with respect to the door **10** of the vehicle **1**. Accordingly, in the vehicle door device **30** according to the present embodiment, the link mechanisms **20**, **20** constituting the first and second link mechanisms **51**, **52** each have a configuration as a four-bar link mechanism independent of each other.

(23) Specifically, first and second link arms **71**, **72** forming the first link mechanism **51** each have a first rotary coupling point **X1** rotatably coupled to the vehicle body **2** in the vicinity of a front edge portion **3f** of the door opening **3**. The first and second link arms **71**, **72** each have a second rotary coupling point **X2** rotatably coupled to the first door **41** constituting the front door **31** of the vehicle **1**. Further, first and second link arms **81**, **82** forming the second link mechanism **52** each have a first rotary coupling point **X1** rotatably coupled to the vehicle body **2** in the vicinity of a rear edge portion **3r** of the door opening **3**. The first and second link arms **81**, **82** each have a second rotary coupling point **X2** rotatably coupled to the second door **42** constituting the rear door **32** of the vehicle **1**.

(24) In the first and second link mechanisms **51**, **52**, the first link arms **71**, **81** are disposed above the second link arms **72**, **82** with which the first link arms **71**, **81** are paired. Specifically, the first link arms **71**, **81** are disposed at heights below windows **91**, **92** of the vehicle **1** formed of the front door **31** and the rear door **32** respectively, that is, near a so-called belt line. The second link arms **72**, **82** are disposed at heights in the vicinity of lower end portions **31b**, **32b** of the front door **31** and the rear door **32**, respectively.

(25) That is, in the vehicle door device **30** according to the present embodiment, the first link arms **71**, **81** have the second rotary coupling points **X2** at positions that are closer to centers of gravity of the front door **31** and the rear door **32** than are the second link arms **72**, **82**. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that, in both the first and second link mechanisms **51**, **52**, the first link arms **71**, **81** support a larger door load than the second link arms **72**, **82**.

(26) Specifically, in the vehicle door device **30** according to the present embodiment, each of the second link arms **72**, **82** positioned as a sub-link **94** is formed using one shaft-shaped member. On the other hand, each of the first link arms **71**, **81** positioned as a main link **95** is formed by coupling two parallel shaft-shaped members. Accordingly, the vehicle door device **30** according to the present embodiment imparts high support rigidity to each of the first link arms **71**, **81**.

(27) More specifically, as shown in FIG. **3**, in the vehicle door device **30** according to the present embodiment, when the front door **31** is opened, the first and second link arms **71**, **72** of the first link mechanism **51** rotate about the first rotary coupling points **X1** in a clockwise direction in FIG. **3**. Accordingly, in the vehicle door device **30** according to the present embodiment, the front door **31** supported by the first and second link arms **71**, **72** is opened toward a vehicle front side.

(28) In the vehicle door device **30** according to the present embodiment, when the front door **31** is closed, the first and second link arms **71**, **72** rotate about the first rotary coupling points **X1** in a counterclockwise direction in FIG. **3**. Accordingly, in the vehicle door device **30** according to the present embodiment, the front door **31** supported by the first and second link arms **71**, **72** is closed toward a vehicle rear side.

(29) On the other hand, in the vehicle door device **30** according to the present embodiment, when the rear door **32** is opened, the first and second link arms **81**, **82** of the second link mechanism **52** rotate about the first rotary coupling points **X1** in the counterclockwise direction in FIG. **3**. Accordingly, in the vehicle door device **30** according to the present embodiment, the rear door **32** supported by the first and second link arms **81**, **82** is opened toward the vehicle rear side.

(30) Further, in the vehicle door device **30** according to the present embodiment, when the rear door **32** is closed, the first and second link arms **81**, **82** rotate about the first rotary coupling points **X1** in the clockwise direction in FIG. **3**. Accordingly, in the vehicle door device **30** according to the

present embodiment, the rear door **32** supported by the first and second link arms **81, 82** is closed toward the vehicle front side.

(31) That is, in the vehicle door device **30** according to the present embodiment, opening and closing trajectories **R1** of the front door **31** are defined in a manner of drawing arc-shaped trajectories **Rg** based on the movement of the first link mechanism **51** formed of the first and second link arms **71, 72**. Similarly, opening and closing trajectories **R2** of the rear door **32** are defined in a manner of drawing the arc-shaped trajectories **Rg** based on the movement of the second link mechanism **52** formed of the first and second link arms **81, 82**.

(32) That is, in the vehicle door device **30** according to the present embodiment, when the doors **10, 10** supported by the link mechanisms **20, 20** approach a fully closed position **P0**, the first and second link arms **61, 62** extend in the vehicle front-rear direction. Accordingly, movement components of the doors **10, 10** constituting the front door **31** and the rear door **32** of the vehicle **1** in the vehicle width direction are increased.

(33) At an intermediate opening and closing position where the first and second link arms **61, 62** forming the link mechanisms **20, 20** extend in the vehicle width direction, the movement components of the doors **10, 10** in the vehicle front-rear direction are increased. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that, when the front door **31** and the rear door **32** of the vehicle **1** are opened and closed, a displacement amount in the vehicle width direction is reduced, thereby avoiding interference with an obstacle and securing a larger door opening amount.

(34) As shown in FIGS. **4** to **6**, in the vehicle door device **30** according to the present embodiment, the second link mechanism **52** supporting the rear door **32** includes a coupling length variable mechanism **100** provided in the second link arm **82**. Further, in the vehicle door device **30** according to the present embodiment, a coupling length **L** between the first and second rotary coupling points **X1, X2** of the second link arm **82** on a second link mechanism **52** side can be changed based on an operation of the coupling length variable mechanism **100**.

(35) Specifically, as shown in FIGS. **5** and **6**, in the vehicle door device **30** according to the present embodiment, the second link arm **82** on the second link mechanism **52** side includes a vehicle body side link **101** and a door side link **102**. That is, the vehicle body side link **101** has the first rotary coupling point **X1** with respect to the vehicle body **2**. The door side link **102** has the second rotary coupling point **X2** with respect to the rear door **32** of the vehicle **1**. Further, the second link arm **82** on the second link mechanism **52** side has a configuration in which the vehicle body side link **101** and the door side link **102** are rotatably coupled to each other. In the vehicle door device **30** according to the present embodiment, a joint link mechanism **110** formed thereby functions as the coupling length variable mechanism **100**.

(36) Specifically, the door side link **102** according to the present embodiment has a configuration as a so-called mini-arm whose axial length is shorter than that of the vehicle body side link **101**. The vehicle body side link **101** includes a vehicle body side coupling portion **111** with respect to the vehicle body **2** on one end side of the vehicle body side link **101** in a longitudinal direction. Further, the door side link **102** also includes a door side coupling portion **112** with respect to the door **10** on one end side of the door side link **102** in the longitudinal direction. The vehicle body side link **101** and the door side link **102** respectively have intermediate coupling portions **113, 114** coupled to each other on the other end sides in the longitudinal direction.

(37) That is, in the vehicle door device **30** according to the present embodiment, the intermediate coupling portions **113, 114** form an intermediate coupling point **X3** of the joint link mechanism **110** provided in the second link arm **82** on the second link mechanism **52** side. In the second link arm **82**, the vehicle body side link **101** and the door side link **102** form a triangle with the intermediate coupling point **X3** as a vertex. Accordingly, the vehicle body side link **101** and the door side link **102** rotate relative to each other. Therefore, a length of a straight line connecting the first and second rotary coupling points **X1, X2** serving as a base of the triangle, that is, the coupling length **L**

of the straight line changes.

(38) In the vehicle door device **30** according to the present embodiment, a biasing member (not shown) applies a biasing force to the joint link mechanism **110** constituting the coupling length variable mechanism **100** to relatively rotate the vehicle body side link **101** and the door side link **102** about the intermediate coupling point **X3**. That is, the coupling length variable mechanism **100** according to the present embodiment is biased in a direction to shorten the coupling length **L** of the rear door **32** by the second link arm **82** on the second link mechanism **52** side provided with the coupling length variable mechanism **100**. Accordingly, in the vehicle door device **30** according to the present embodiment, the rear door **32** is opened and closed in a state in which the coupling length **L** is shortened by the second link arm **82**, except for a case in which the rear door **32**, which will be described in detail below, is in the vicinity of the fully closed position **P0**.

(39) As shown in FIGS. **4** to **7**, in the vehicle door device **30** according to the present embodiment, the opening and closing trajectory **R2** of the rear door **32** changes based on the operation of the coupling length variable mechanism **100** provided in the second link arm **82** on the second link mechanism **52** side. Specifically, when the rear door **32** is in the vicinity of the fully closed position **P0**, the opening and closing trajectory **R2** of the rear door **32** changes to a linear trajectory **Rs**. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that the front door **31** and the rear door **32**, which are independently opened and closed, do not interfere with each other based on the operations of the first and second link mechanisms **51**, **52**.

(40) More specifically, in the vehicle **1** according to the present embodiment, the front door **31** is closed toward the vehicle rear side with a rear end portion **31r** of the front door **31** as a closing end portion **131**. The rear door **32** is closed toward the vehicle front side with a front end portion **32f** of the rear door **32** as a closing end portion **132**. Further, the front door **31** and the rear door **32** are disposed at the fully closed position **P0** in a state in which a closing end portion tip end **131x** of the front door **31** and a closing end portion tip end **132x** of the rear door **32** overlap each other in the vehicle width direction.

(41) Specifically, in the vehicle **1** according to the present embodiment, the closing end portion tip end **132x** on a rear door **32** side located at the front end portion **32f** of the rear door **32** is disposed on an inner side in the vehicle width direction (an upper side in FIG. **7**). The closing end portion tip end **131x** on a front door **31** side located at the rear end portion **31r** of the front door **31** is disposed on an outer side in the vehicle width direction (a lower side in FIG. **7**) with respect to the closing end portion tip end **132x** on the rear door **32** side. Therefore, when it is assumed that both of the front door **31** and the rear door **32** are opened and closed on the arc-shaped trajectory **Rg** based on the rotation of the first and second link arms **61**, **62** even in the vicinity of the fully closed position **P0**, the doors **10**, **10** interfere with each other.

(42) That is, in such an assumption, when the rear door **32** located at the fully closed position **P0** is opened, the front door **31** having the closing end portion tip end **131x** disposed on an outer side in the vehicle width direction with respect to the closing end portion tip end **132x** of the rear door **32** needs to be opened from the fully closed position **P0** first. Further, when the front door **31** is fully closed, the rear door **32** needs to be in the fully closed state before the front door **31** is fully closed.

(43) In consideration of this point, in the vehicle door device **30** according to the present embodiment, as described above, when the rear door **32** is located in the vicinity of the fully closed position **P0**, the opening and closing trajectory **R2** of the rear door **32** changes based on the operation of the coupling length variable mechanism **100**. Specifically, in the vehicle door device **30** according to the present embodiment, when the rear door **32** is fully closed, the rear door **32** moves to the fully closed position **P0** in such a manner that the closing end portion tip end **132x** of the rear door **32** draws the linear trajectory **Rs** from the vehicle rear side to the front side (from the right side to the left side in FIG. **7**). When the rear door **32** is opened from the fully closed state, the rear door **32** moves from the fully closed position **P0** in such a manner that the closing end portion tip end **132x** of the rear door **32** similarly draws the linear trajectory **Rs** from the vehicle front side

to the rear side (from the left side to the right side in FIG. 7). Accordingly, in the vehicle door device **30** according to the present embodiment, the front door **31** and the rear door **32** of the vehicle **1** can be opened and closed independently of each other without an order restriction when it is assumed that both of the front door **31** and the rear door **32** are opened and closed along the arc-shaped trajectory *Rg* as described above.

(44) More specifically, as shown in FIGS. **4**, **8**, and **9**, the vehicle door device **30** according to the present embodiment includes a door side engagement portion **133** provided at the closing end portion **132** of the rear door **32**. The vehicle door device **30** includes a vehicle body side engagement portion **134** provided at a position corresponding to a front end **5f** of the rear opening **5** constituting the door opening **3** of the vehicle **1**, that is, at a substantially central position in the opening width direction of the door opening **3** extending in the vehicle front-rear direction. Further, in the vehicle door device **30** according to the present embodiment, when the rear door **32** is in the vicinity of the fully closed position **P0**, the door side engagement portion **133** and the vehicle body side engagement portion **134** are engaged with each other.

(45) Specifically, as shown in FIGS. **4** and **9**, the vehicle door device **30** according to the present embodiment includes a pair of door side engagement portions **133**, **133** provided at an upper end portion **32fa** and a lower end portion **32fb** of the front end portion **32f** of the rear door **32**, which is the closing end portion **132** of the rear door **32**. The vehicle door device **30** includes a pair of vehicle body side engagement portions **134**, **134** that are provided at an upper edge portion **3a** and a lower edge portion **3b** of the door opening **3** at the substantially central position in the opening width direction of the door opening **3**.

(46) That is, in the vehicle **1** according to the present embodiment, the substantially central position in the opening width direction of the door opening **3** extending in the vehicle front-rear direction is the position of a rear end **4r** of the front opening **4** and the front end **5f** of the rear opening **5**.

Further, in the vehicle door device **30** according to the present embodiment, the substantially central position corresponds to the closing end portions **135**, **136** of the door opening **3** in which the front door **31** and the rear door **32** are provided side by side in the opening width direction.

(47) That is, the door opening **3** according to the present embodiment has the so-called pillarless structure as described above. Therefore, the vehicle door device **30** according to the present embodiment is implemented such that the vehicle body side engagement portions **134**, **134** are provided at the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3**.

(48) As shown in FIGS. **8** and **10**, in the vehicle door device **30** according to the present embodiment, the door side engagement portion **133** includes a shaft-shaped engagement portion **151** that extends in an upper-lower direction (a direction orthogonal to a paper surface in FIG. **8**) of the vehicle **1**. Further, the vehicle body side engagement portion **134** has a guide groove **152** having a pair of side wall portions **152a**, **152b** facing each other in the vehicle width direction (an upper-lower direction in FIG. **8**) and extending in an opening and closing direction of the rear door **32**. Further, in the vehicle door device **30** according to the present embodiment, when the rear door **32** is in the vicinity of the fully closed position **P0**, the door side engagement portion **133** and the vehicle body side engagement portion **134** are engaged with each other in a state in which the shaft-shaped engagement portion **151** is disposed in the guide groove **152**.

(49) That is, the shaft-shaped engagement portion **151** of the door side engagement portion **133** is disposed in the guide groove **152** of the vehicle body side engagement portion **134**, in a state of being sandwiched between the pair of side wall portions **152a**, **152b** facing each other in the vehicle width direction. Therefore, the displacement of the rear door **32** in the vehicle width direction is restricted. Accordingly, the vehicle door device **30** according to the present embodiment can stably support the rear door **32** even in the vicinity of the fully closed position **P0** where the first and second link arms **81**, **82** forming the second link mechanism **52** are likely to be aligned.

(50) Further, in the vehicle door device **30** according to the present embodiment, the opening and



closing of the rear door **32** in the state in which the door side engagement portion **133** and the vehicle body side engagement portion **134** are engaged with each other is allowed based on the operation of the coupling length variable mechanism **100** provided in the second link arm **82**. Specifically, when the rear door **32** is opened and closed in the state in which the door side engagement portion **133** and the vehicle body side engagement portion **134** are engaged with each other, the shaft-shaped engagement portion **151** is relatively displaced along an extending direction of the guide groove **152** while the coupling length  $L$  is changed based on the operation of the coupling length variable mechanism **100**. Accordingly, in the vehicle door device **30** according to the present embodiment, the opening and closing trajectory  $R2$  of the rear door **32** changes. That is, the arc-shaped trajectory  $Rg$  based on the operation of the second link mechanism **52** is changed to the linear trajectory  $Rs$  along the opening width direction of the door opening **3**.

(51) In the vehicle door device **30** according to the present embodiment, on a first link mechanism **51** side supporting the front door **31** of the vehicle **1**, the coupling length variable mechanism **100** is not provided in any of the first and second link arms **71**, **72**. That is, in the vehicle door device **30** according to the present embodiment, even when the front door **31** is in the vicinity of the fully closed position  $P0$ , the front door **31** is opened and closed while drawing the arc-shaped trajectory  $Rg$  based on the rotation of the first and second link arms **71**, **72**. Accordingly, in the vehicle **1** according to the present embodiment, the front door **31** located in the vicinity of the fully closed position  $P0$  is opened and closed in a manner of being displaced in the vehicle width direction.

(52) That is, when the front door **31** is opened from the fully closed position  $P0$ , the rear end portion **311**, which is the closing end portion **131** of the front door **31**, is displaced in the outer side in the vehicle width direction while being displaced toward the vehicle front side. On the other hand, when the front door **31** is closed to the fully closed position  $P0$ , the rear end portion **31r**, which serves as the closing end portion **131** of the front door **31**, is displaced in the inner side in the vehicle width direction while being displaced toward the vehicle rear side. Accordingly, the vehicle door device **30** according to the present embodiment can open the front door **31** of the vehicle **1** from the fully closed position  $P0$  and close the front door **31** to the fully closed position  $P0$  with an operation feeling similar to that of a general swing door.

(53) As shown in FIGS. **1** to **4**, the vehicle door device **30** according to the present embodiment has a configuration as a so-called power door device capable of opening and closing the front door **31** and the rear door **32** of the vehicle **1** based on a driving force of an actuator **160**.

(54) Specifically, the vehicle door device **30** according to the present embodiment includes a first actuator **161** that applies the driving force to the first link mechanism **51** to open and close the first door **41** supported by the first link mechanism **51**. The vehicle door device **30** further includes a second actuator **162** that applies the driving force to the second link mechanism **52** to open and close the second door **42** supported by the second link mechanism **52**. In the vehicle door device **30** according to the present embodiment, the front door **31** serving as the first door **41** and the rear door **32** serving as the second door **42** are independently opened and closed by operations of the first and second actuators **161**, **162**.

(55) Specifically, the first and second actuators **161**, **162** each have a motor serving as a drive source thereof. The first and second actuators **161**, **162** are provided at the first rotary coupling points  $X1$ ,  $X1$  of the first link arms **71**, **81**, respectively, in the corresponding first and second link mechanisms **51**, **52**.

(56) Specifically, the first actuator **161** is provided at a base end portion **71x** of the first link arm **71** having the first rotary coupling point  $X1$  with respect to the vehicle body **2** in a state in which the first actuator **161** is fixed to the vehicle body **2**. Specifically, the first actuator **161** is provided at a position where the base end portion **71x** of the first link arm **71** and a coupling bracket **163** that allows the base end portion **71x** to rotate with respect to the vehicle body **2** are coupled.

Accordingly, the first actuator **161** is implemented such that a driving force for rotating the first link arm **71** on the first link mechanism **51** side about the first rotary coupling point  $X1$  with

respect to the vehicle body **2** is applied.

(57) Similarly, the second actuator **162** is also provided at a base end portion **81x** of the first link arm **81** having the first rotary coupling point **X1** with respect to the vehicle body **2** in a state in which the second actuator **162** is fixed to the vehicle body **2**. Specifically, the second actuator **162** is provided at a position where the base end portion **81x** of the first link arm **81** and a coupling bracket **164** that allows the base end portion **81x** to rotate with respect to the vehicle body **2** are coupled. Accordingly, in the second actuator **162**, a driving force for rotating the first link arm **81** on the second link mechanism **52** side about the first rotary coupling point **X1** with respect to the vehicle body **2** is applied.

(58) Further, in the vehicle door device **30** according to the present embodiment, independent control signals are input to the first and second actuators **161**, **162**, respectively. Accordingly, in the vehicle **1** according to the present embodiment, the front door **31** supported by the first link mechanism **51** and the rear door **32** serving as the second door **42** supported by the second link mechanism **52** are opened and closed independently of each other.

(59) Door Lock System

(60) Next, a door lock system of the vehicle **1** formed of the vehicle door device **30** according to the present embodiment will be described.

(61) As shown in FIGS. **4**, **9**, and **10**, the vehicle door device **30** according to the present embodiment includes strikers **171**, **172** provided at the front edge portion **3f** and the rear edge portion **3r** of the door opening **3**. The vehicle door device **30** includes a pair of upper and lower strikers **173**, **174** separately provided at the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3** at the substantially central position in the opening width direction of the door opening **3**. Specifically, the strikers **173**, **174** are provided at the closing end portion **135** of the door opening **3** where the front door **31** is disposed. The vehicle door device **30** further includes a striker **175** provided at the front end portion **32f** of the rear door **32**. Accordingly, the vehicle door device **30** according to the present embodiment includes a plurality of lock devices **180** that engage with the strikers **171** to **175** to restrain the front door **31** and the rear door **32** that are provided in the door opening **3** at the fully closed position **P0**.

(62) Specifically, as shown in FIG. **9**, the vehicle door device **30** according to the present embodiment includes, as the lock device **180**, a front lock **181** provided at a front end portion **31f** of the front door **31**. Similarly, the vehicle door device **30** includes, as the lock device **180**, a rear lock **182** provided at a rear end portion **32r** of the rear door **32**. Further, the vehicle door device **30** includes, as the lock devices **180**, an upper lock **183** provided at an upper end portion **31ra** of the rear end portion **31r** of the front door **31**, and a lower lock **184** provided at a lower end portion **31rb** of the rear end portion **31r** of the front door **31**. The vehicle door device **30** according to the present embodiment includes, as the lock device **180**, a center lock **185** provided at the rear end portion **31r** of the front door **31** at a position in the upper-lower direction between the upper lock **183** and the lower lock **184**.

(63) That is, in the vehicle **1** according to the present embodiment, when the front door **31** is closed to the fully closed position **P0**, the lock devices **180** provided at the front door **31** are engaged with the corresponding strikers **171**, **173**, **174**. Specifically, the front lock **181** provided at the front end portion **31f** of the front door **31** is engaged with the striker **171** provided at the front edge portion **3f** of the door opening **3**, that is, at a position corresponding to a front end **4f** of the front opening **4**. The upper lock **183** and the lower lock **184** provided at the rear end portion **31r** of the front door **31** separately engage with the upper and lower strikers **173**, **174** provided at the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3** at positions corresponding to the rear end **4r** of the front opening **4**. In the vehicle **1** according to the present embodiment, the strikers **173**, **174** are similarly disposed on the vehicle front side of the vehicle body side engagement portions **134**, **134** that are provided on the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3**. Further, in the vehicle **1** according to the present embodiment, the front door **31** is held in the fully

closed state based on an engagement force between the strikers **171**, **173**, **174** and the front lock **181**, the upper lock **183**, and the lower lock **184**.

(64) When the rear door **32** is closed to the fully closed position **P0**, the rear lock **182** provided at the rear end portion **32r** of the rear door **32** is engaged with the striker **172** provided at the rear edge portion **3r** of the door opening **3**, that is, at a position corresponding to a rear end **5r** of the rear opening **5**. Further, in the vehicle **1** according to the present embodiment, the rear door **32** is held in the fully closed state based on an engagement force of the rear lock **182** and the striker **172** and an engagement force of the door side engagement portions **133**, **133** and the vehicle body side engagement portions **134**, **134**.

(65) Further, in the vehicle **1** according to the present embodiment, when both the front door **31** and the rear door **32** are in the fully closed state, the center lock **185** provided in the front door **31** is engaged with the striker **175** provided in the rear door **32**. That is, the lock device **180** provided at the closing end portion **131** of the front door **31** engages with the striker **175** provided at the closing end portion **132** of the rear door **32**. Accordingly, the vehicle **1** according to the present embodiment is implemented such that the front door **31** and the rear door **32** are restrained at the fully closed position **P0** based on an engagement force of the center lock **185** and the striker **175**.

(66) More specifically, in the vehicle door device **30** according to the present embodiment, the lock devices **180** each include a latch mechanism (not shown) that has two engagement states which are a half-latched state and a full-latched state. Each of the lock devices **180** other than the upper lock **183** includes a motor **190** serving as a drive source. That is, each of the lock devices **180** has a function of shifting the latch mechanism from the half-latched state to the full-latched state and shifting the latch mechanism from the full-latched state to an unlatched state, that is, a non-engaged state, by motor driving. Further, the vehicle door device **30** according to the present embodiment is implemented such that the lower lock **184** and the upper lock **183** having the drive source thereof are interlocked with each other by cable coupling via a remote controller **191f**. Further, the vehicle door device **30** according to the present embodiment releases, by the operation of the lock devices **180**, the restraint of the front door **31** and the rear door **32** in response to an opening request when the door is opened from the fully closed position **P0**.

(67) Specifically, in the vehicle **1** according to the present embodiment, a control signal for each lock device **180** having the motor **190** serving as the drive source is individually input via an in-vehicle network (not shown).

(68) For example, when an opening request of the rear door **32** is made based on an operation input to an operation switch provided in the vehicle **1** or a portable device held by a user, a lock release signal is input to the lock device **180** provided in the rear door **32**, that is, the rear lock **182**. At this time, the lock release signal is also input to the lock device **180** that engages with the striker **175** provided at the front end portion **32f** of the rear door **32**, that is, the center lock **185**, among the lock devices **180** provided at the rear end portion **31r** of the front door **31**. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that the rear lock **182** and the center lock **185** perform an unlock operation, thereby allowing the opening of the rear door **32** in the fully closed state.

(69) On the other hand, when an opening request of the front door **31** is made, the lock release signal is input to the lock devices **180** with the drive source provided in the front door **31**, that is, the front lock **181**, the lower lock **184**, and the center lock **185**. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that the three lock devices **180** perform the unlock operation, and the upper lock **183** is interlocked to perform the unlock operation, thereby allowing the opening of the front door **31** in the fully closed state.

(70) In the vehicle door device **30** according to the present embodiment, in addition to the upper lock **183** and the lower lock **184**, the front lock **181** and the center lock **185** are also coupled to the remote controller **191f** provided on the front door **31** via a transmission cable **193**. Similarly, the rear lock **182** on the rear door **32** side is coupled to a remote controller **191r** provided on the rear

door **32** via a transmission cable **193**. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that each of the lock devices **180** performs the unlock operation based on an operation of the remote controllers **191f**, **191r** coupled via the transmission cable **193** without depending on the motor driving.

(71) Specifically, the vehicle **1** according to the present embodiment includes emergency levers (not shown) provided on the front door **31** and the rear door **32**. In the vehicle door device **30** according to the present embodiment, operation inputs to the emergency levers are separately input to the remote controller **191f** on the front door **31** side and the remote controller **191r** on the rear door **32** side on which the respective emergency levers are provided. That is, in the vehicle **1** according to the present embodiment, the emergency levers are operated at, for example, the time of power loss such as so-called battery exhaustion. Further, the operation inputs to the emergency levers are separately transmitted to the lock devices **180** provided in the front door **31** and the rear door **32** via the corresponding remote controllers **191f**, **191r**. Accordingly, the vehicle door device **30** according to the present embodiment can manually release the restraint of the front door **31** and the rear door **32** that are held in the fully closed state.

(72) Front Door and First Link Mechanism

(73) Next, the first link mechanism **51** supporting the front door **31** of the vehicle **1** will be described.

(74) As shown in FIGS. **4** and **11** to **13**, in the vehicle **1** according to the present embodiment, the first door **41** constituting the front door **31** of the vehicle **1** is disposed in the front opening **4** of the door opening **3** while being supported by the first link mechanism **51**. Accordingly, the vehicle door device **30** according to the present embodiment is implemented such that the front door **31** is opened and closed on the outer side in the vehicle width direction of a front seat **201** provided in a vehicle interior **200** based on the operation of the first link mechanism **51**.

(75) That is, as described above, the first and second link arms **71**, **72** forming the first link mechanism **51** each have the first rotary coupling point **X1** rotatably coupled to the vehicle body **2** in the vicinity of the front edge portion **3f** of the door opening **3**.

(76) Specifically, as shown in FIGS. **11** to **14**, the vehicle **1** according to the present embodiment includes a front portion **200f** of the vehicle interior **200** and a dash panel **210** provided at a position in front of a front seat **201** of the front portion **200f**. Further, in the vehicle door device **30** according to the present embodiment, the first link arm **71** constituting the main link **95** of the first link mechanism **51** has the first rotary coupling point **X1** with respect to the vehicle body **2** inside the dash panel **210**. Specifically, in the vehicle door device **30** according to the present embodiment, the base end portion **71x** of the first link arm **71** and the coupling bracket **163** forming the first rotary coupling point **X1** with respect to the vehicle body **2** are disposed inside the dash panel **210**. Accordingly, in the vehicle door device **30** according to the present embodiment, the first link arm **71** rotates in a state in which the first rotary coupling point **X1** and the first actuator **161** provided at the first rotary coupling point **X1** are hidden in the dash panel **210**. That is, the front door **31** of the vehicle **1** coupled to the first link arm **71** is opened and closed.

(77) The vehicle door device **30** according to the present embodiment includes a link cover **220** that rotates together with the first link arm **71** in a state of covering the first link arm **71** constituting the first link mechanism **51**. In the vehicle door device **30** according to the present embodiment, the link cover **220** is implemented using a soft material, such as resin or sponge, similar to a door trim constituting an inner side surface **31s** of the front door **31**. The link cover **220** according to the present embodiment covers an outer periphery of the first link arm **71** over the entire length of the first link arm **71** from the first rotary coupling point **X1** with respect to the vehicle body **2** to the second rotary coupling point **X2** with respect to the front door **31**. Further, in the vehicle door device **30** according to the present embodiment, when the front door **31** is in the fully closed state, the link cover **220** is continuously and integrally disposed with the inner side surface **31s** of the front door **31** and the dash panel **210**.

(78) That is, as shown in FIGS. 13 and 14, in the vehicle door device 30 according to the present embodiment, when the front door 31 is in the fully closed state, the first and second link arms 71, 72 of the first link mechanism 51 supporting the front door 31 extend in the vehicle front-rear direction. Accordingly, the link cover 220 covering the first link arm 71 is disposed along the inner side surface 31s of the front door 31. In this state, the link cover 220 according to the present embodiment is designed to be integrated with the inner side surface 31s of the front door 31.

(79) Further, in the link cover 220 according to the present embodiment, a portion covering the base end portion 71x of the first link arm 71 having the first rotary coupling point X1 with respect to the vehicle body 2 has a substantially L-shaped curved shape. Accordingly, the vehicle door device 30 according to the present embodiment is implemented such that, when the front door 31 is in the fully closed state, a base end portion 221 of the link cover 220 is continuously disposed on a design surface 210s of the dash panel 210 extending in the vehicle width direction.

(80) As shown in FIGS. 12 and 14, the vehicle door device 30 according to the present embodiment includes a cover member 240 provided in a gap 230 formed between the link cover 220 and the dash panel 210 when the front door 31 is opened.

(81) That is, in the vehicle door device 30 according to the present embodiment, the first link mechanism 51 is in a state in which the first and second link arms 71, 72 extend in the vehicle width direction by the opening of the front door 31. Accordingly, a base end portion 221 side of the link cover 220, which has the substantially L-shaped curved shape and is continuous with the design surface 210s of the dash panel 210, faces the vehicle rear side. Accordingly, the gap 230 between the link cover 220 and the dash panel 210 is enlarged.

(82) In view of this point, in the vehicle door device 30 according to the present embodiment, the cover member 240 disposed in the gap 230 covers the base end portion 71x of the first link arm 71 and the first actuator 161 disposed in the dash panel 210. That is, the cover member 240 hides the base end portion 71x of the first link arm 71 and the first actuator 161 facing a vehicle interior 200 side from the gap 230 between the link cover 220 and the dash panel 210. Accordingly, in the vehicle door device 30 according to the present embodiment, high design characteristics are secured.

(83) As shown in FIGS. 11 to 13 and 15, in the vehicle 1 according to the present embodiment, a lower side of the dash panel 210 is a foot space 250 of an occupant seated on the front seat 201. Further, an interior member 251 that covers an inner side surface (not shown) of the vehicle body 2 that forms a wall surface of the vehicle interior 200 is provided at a position on a side of the foot space 250 formed below the dash panel 210 and on an outer side in the vehicle width direction. The interior member 251 may be referred to as “foot scuff”, for example. In the vehicle door device 30 according to the present embodiment, the second link arm 72 constituting the sub-link 94 of the first link mechanism 51 has the first rotary coupling point X1 with respect to the vehicle body 2 inside the interior member 251 disposed on the side of the foot space 250. Specifically, in the vehicle door device 30 according to the present embodiment, the base end portion 72x of the second link arm 72 and a coupling bracket 252 forming the first rotary coupling point X1 are disposed inside the dash panel 210.

(84) That is, in the vehicle 1 according to the present embodiment, due to the arrangement, the base end portion 72x of the second link arm 72 having the first rotary coupling point X1 with respect to the vehicle body 2 is difficult to be seen by the occupant of the vehicle 1. Accordingly, in the vehicle door device 30, high design characteristics are secured.

(85) As shown in FIG. 16, in the vehicle door device 30 according to the present embodiment, due to the arrangement of the first rotary coupling point X1 with respect to the vehicle body 2, the front door 31 supported by the second link arm 72 is less likely to interfere with getting on and off through the door opening 3.

(86) That is, the second link arm 72 supporting the lower end portion 31b of the front door 31 operates at a height overlapping a flow line of the feet of the occupant on the front seat 201 when

the occupant gets on and off the vehicle. In FIG. 16, a dashed-dotted line  $\alpha$  indicates a flow line of the feet of the occupant seated on the front seat 201, specifically, a flow line of heels of the occupant when the occupant gets on and off the vehicle. However, in the vehicle door device 30 according to the present embodiment, in a state in which the front door 31 is in a fully opened position P1, the second link arm 72 supporting the front door 31 is disposed at a position deviated from the flow line of the occupant who gets on and off the vehicle 1. Further, as for a door opening amount of the front door 31 in the fully open state, substantially the same door opening amount is secured as in the case of using a general swing door indicated by a virtual line in FIG. 16.

Accordingly, in the vehicle door device 30 according to the present embodiment, the front opening 4 of the door opening 3 in which the front door 31 is provided is capable of securing good getting-on-and-off performance.

(87) As shown in FIGS. 13, 15, and 17, in the vehicle 1 according to the present embodiment, an accommodation recess 253 for accommodating the second link arm 72 therein when the front door 31 is closed is formed in the inner side surface 31s of the front door 31. The vehicle door device 30 according to the present embodiment includes a lid member 254 that covers an opening 253x in a state in which the second link arm 72 is accommodated in the accommodation recess 253.

(88) Specifically, the accommodation recess 253 according to the present embodiment has a groove shape extending in the vehicle front-rear direction in the vicinity of the lower end portion 31b of the front door 31. Further, the lid member 254 has a rotary shaft (not shown) at a position above the accommodation recess 253. That is, in the vehicle door device 30 according to the present embodiment, the second link arm 72 is detached from the accommodation recess 253 in a manner of pushing up the lid member 254 when the front door 31 is opened (see FIG. 15). When the front door 31 is closed, the lid member 254 is rotated by an own weight thereof and thereby returned to the position where the lid member 254 covers the opening 253x of the accommodation recess 253 for accommodating the second link arm 72 therein. Accordingly, the vehicle door device 30 according to the present embodiment is implemented such that, when the front door 31 is in the fully closed state, it is difficult for the occupant in the vehicle interior 200 to visually recognize the second link arm 72 forming the first link mechanism 51.

(89) Next, an operation according to the present embodiment will be described.

(90) That is, the front door 31 supported by the first link mechanism 51 that does not include the coupling length variable mechanism 100 is closed to the fully closed position P0 and opened from the fully closed position P0 while drawing the arc-shaped trajectory Rg based on the rotation of the first and second link arms 71, 72. That is, the front door 31 is closed to the fully closed position P0 when the closing end portion tip end 131x moves to the inner side in the vehicle width direction, and is opened from the fully closed position P0 when the closing end portion tip end 131x moves to the outer side in the vehicle width direction.

(91) On the other hand, when the rear door 32 supported by the second link mechanism 52 is in the vicinity of the fully closed position P0, the opening and closing trajectory R2 of the rear door 32 changes based on the operation of the coupling length variable mechanism 100 provided in the second link arm 82. Specifically, the opening and closing trajectory R2 changes from the arc-shaped trajectory Rg based on the rotation of the first and second link arms 81, 82 to the linear trajectory Rs based on the operation of the coupling length variable mechanism 100. That is, the closing end portion tip end 132x of the rear door 32 moves from the vehicle rear side to the front side to close the rear door 32 to the fully closed position P0, and the closing end portion tip end 121x of the rear door 32 moves from the vehicle front side to the rear side to open the rear door 32 from the fully closed position P0. Accordingly, the front door 31 and the rear door 32 can be opened and closed independently of each other without any order restriction.

(92) Next, effects according to the present embodiment will be described.

(93) (1) The vehicle door device 30 includes the first link mechanism 51 formed of the first and second link arms 71, 72 having the first rotary coupling point X1 with respect to the vehicle body 2

and the second rotary coupling point X2 with respect to the door **10** of the vehicle **1**. The vehicle door device **30** includes the second link mechanism **52** formed of the first and second link arms **81**, **82** provided independently of the first and second link arms **71**, **72** forming the first link mechanism **51**. Further, the first door **41** supported by the first link mechanism **51** and the second door **42** supported by the second link mechanism **52** are disposed side by side in the door opening **3** formed in the vehicle **1**. Further, the first and second doors **41**, **42** are opened and closed independently in different directions based on the operation of the corresponding first and second link mechanisms **51**, **52**. The second link arm **82** constituting the second link mechanism **52** is provided with the coupling length variable mechanism **100** that can change the coupling length L between the first and second rotary coupling points X1, X2.

(94) According to the above configuration, based on the operation of the first and second link mechanisms **51**, **52**, the first and second doors **41**, **42** are opened and closed while drawing the arc-shaped trajectory Rg. That is, when the doors are opened and closed, the first and second doors **41**, **42** move in the vehicle front-rear direction at the intermediate opening and closing position. Accordingly, it is possible to reduce the displacement amount in the vehicle width direction, that is, the displacement amount of the opening and closing when the doors protrude in the opening direction of the door opening **3** in which the first and second doors **41**, **42** are provided. As a result, the interference with an obstacle located in the opening direction of the door opening **3** can be avoided, and a larger door opening amount can be secured.

(95) Further, when the second door **42** supported by the second link mechanism **52** is in the vicinity of the fully closed position P0 based on the operation of the coupling length variable mechanism **100** provided in the second link arm **82**, the opening and closing trajectory R2 can be changed from the arc-shaped trajectory Rg. Accordingly, the interference between the first and second doors **41**, **42** in the vicinity of the fully closed position P0 can be avoided. The first and second doors **41**, **42** can be opened and closed independently of each other without any order restriction.

(96) (2) In particular, by not providing the coupling length variable mechanism **100** on the first link mechanism **51** side and maintaining the opening and closing trajectory R1 of the arc-shaped trajectory Rg, it is possible to stably avoid the interference between the first and second doors **41**, **42** in the vicinity of the fully closed position P0. That is, the opening and closing trajectory R1 of the first door **41** is not changed, so that it is possible to easily identify the opening and closing trajectory of the second door **42** that does not interfere with the first door **41**. Accordingly, high reliability can be secured while simplifying the configuration.

(97) (3) Further, the second link mechanism **52** is implemented such that, when the second door **42** is in the vicinity of the fully closed position P0, the opening and closing trajectory R2 thereof is changed to the linear trajectory Rs along the opening width direction of the door opening **3** based on the operation of the coupling length variable mechanism **100**.

(98) That is, even in the vicinity of the fully closed position P0, the first door **41** supported by the first link mechanism **51** that does not include the coupling length variable mechanism **100** maintains the arc-shaped trajectory Rg based on the operation of the first link mechanism **51**. That is, the first door **41** is closed to the fully closed position P0 by moving to the inner side in the vehicle width direction, and is opened from the fully closed position P0 by moving to the outer side in the vehicle width direction. On the other hand, the second door **42** is closed to the fully closed position P0 by moving from the vehicle rear side to the front side, and is opened from the fully closed position P0 by moving from the vehicle front side to the rear side. Accordingly, the first and second doors **41**, **42** can be opened and closed independently of each other without any order restriction.

(99) (4) The first door **41** is the front door **31** that is opened toward the vehicle front side based on the operation of the first link mechanism **51**. The second door **42** is the rear door **32** that is opened toward the vehicle rear side based on the operation of the second link mechanism **52**.

(100) According to the above configuration, the so-called double opening front door **31** and the so-

called double opening rear door **32** that are opened and closed in opposite directions can be disposed with respect to the door opening **3** provided on the side surface **2s** of the vehicle body **2**. Further, with respect to the front door **31** and the rear door **32**, it is possible to reduce the displacement amount of the opening and closing when the doors protrude in the opening direction of the door opening **3**, that is, to the outer side in the vehicle width direction. Accordingly, for example, it is possible to avoid the interference with an obstacle located in the opening direction of the door opening, such as a wall located in the vehicle width outer direction or a vehicle stopped adjacent thereto, and to secure a larger door opening amount.

(101) The front door **31** and the rear door **32** can be opened and closed independently of each other without any order restriction. Further, in the vicinity of the fully closed position **P0**, the front door **31** supported by the first link mechanism **51** that does not include the coupling length variable mechanism **100** is opened and closed in a manner of being displaced in the vehicle width direction. Accordingly, the front door **31** can be opened from the fully closed position **P0** and closed to the fully closed position **P0** with an operation feeling similar to that of a general swing door.

(102) (5) The vehicle door device **30** includes the door side engagement portion **133** provided at the closing end portion **132** of the rear door **32**. In the vehicle door device **30**, based on the opening and closing of the rear door **32**, a substantially central position in the opening width direction of the door opening **3** which the closing end portion **132** comes into contact with and separates from, that is, a position which is the front end **5f** of the rear opening **5** in which the rear door **32** is provided is set as the closing end portion **136** of the door opening **3**. The vehicle door device **30** includes the vehicle body side engagement portion **134** provided at the closing end portion **136** of the door opening **3**. The door side engagement portion **133** includes the shaft-shaped engagement portion **151** extending in the upper-lower direction of the vehicle **1**. The vehicle body side engagement portion **134** has the guide groove **152** that includes the pair of side wall portions **152a**, **152b** facing each other in the vehicle width direction which is the opening direction of the door opening **3** and that extends in the opening and closing direction of the rear door **32**. In the vehicle door device **30** according to the present embodiment, when the door side engagement portion **133** and the vehicle body side engagement portion **134** are in the vicinity of the fully closed position **P0** of the rear door **32** where the door side engagement portion **133** and the vehicle body side engagement portion **134** are engaged with each other, the shaft-shaped engagement portion **151** is disposed in the guide groove **152**.

(103) According to the above configuration, since the shaft-shaped engagement portion **151** is disposed in the guide groove **152**, the displacement of the rear door **32** is restricted in the vehicle width direction, that is, in the opening direction of the door opening **3**. Accordingly, the rear door **32** can be stably supported even in the vicinity of the fully closed position **P0** where the distance between the first and second link arms **81**, **82** forming the second link mechanism **52** is likely to be reduced and the first and second link arms **81**, **82** are likely to be linearly arranged.

(104) (6) Further, in a state in which the door side engagement portion **133** and the vehicle body side engagement portion **134** are engaged with each other, the opening and closing trajectory **R2** of the rear door **32** changes from the arc-shaped trajectory **Rg** to the linear trajectory **Rs** based on the operation of the coupling length variable mechanism **100**. Accordingly, even when the front door **31** is in the fully closed state, the rear door **32** can be smoothly closed to the fully closed position **P0** and opened from the fully closed position **P0**.

(105) (7) The vehicle door device **30** includes a pair of vehicle body side engagement portions **134**, **134** that are provided at the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3**. The vehicle door device **30** includes a pair of door side engagement portions **133**, **133** that are provided at the closing end portion **132** of the rear door **32** and that engage with the vehicle body side engagement portions **134**, **134**.

(106) According to the above configuration, the rear door **32** can be supported more stably in the vicinity of the fully closed position **P0**. Further, there is an advantage that the embodiment



disclosed here can be applied to a so-called pillarless structure in which the closing end portion **136** of the door opening **3** does not have a structure extending in the upper-lower direction such as a “B pillar”. In the door opening **3**, the vehicle body side engagement portion **134** is disposed.

(107) (8) Further, for the closing end portion **132** of the rear door **32** provided with the pair of door side engagement portions **133**, **133**, the lock device **180** for restraining the rear door **32** at the fully closed position **P0** can be eliminated. That is, even when the rear door **32** is in the fully closed state, it is possible to stably hold the closing end portion **132** of the rear door **32** based on an engagement force of the pair of door side engagement portions **133**, **133** and the pair of vehicle body side engagement portions **134**, **134** that are provided at the closing end portion **132**.

Accordingly, it is possible to stably support the rear door **32** at the fully closed position **P0** while simplifying the configuration.

(108) (9) The vehicle door device **30** includes the pair of strikers **173**, **174** provided at the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3**. Further, the vehicle door device **30** includes the upper lock **183** and the lower lock **184** as a pair of lock devices **180** that are provided at the closing end portion **131** of the front door **31** and that engage with the strikers **173**, **174**.

(109) According to the above configuration, the front door **31** can be stably restrained at the fully closed position **P0**. Further, there is an advantage that the embodiment disclosed here can be applied to a so-called pillarless structure in which the closing end portion **135** of the door opening **3** does not have a structure extending in the upper-lower direction such as a “B pillar”. In the door opening **3**, the striker is to be disposed.

(110) (10) The vehicle door device **30** includes the striker **175** provided at the closing end portion **132** of the rear door **32**, and the center lock **185** as the lock device **180** provided at the closing end portion **131** of the front door **31**. When the striker **175** and the center lock **185** are engaged with each other, the front door **31** and the rear door **32** are restrained at the fully closed position.

(111) According to the above configuration, even when the door opening **3** has the so-called pillarless structure in which the closing end portions **135**, **136** thereof do not have a structure extending in the upper-lower direction such as a “B pillar”, the front door **31** and the rear door **32** can be stably restrained at the fully closed position **P0**.

(112) (11) The vehicle door device **30** includes the first actuator **161** that applies a driving force to the first link mechanism **51** to open and close the front door **31**, and the second actuator **162** that applies a driving force to the second link mechanism **52** to open and close the rear door **32**. Accordingly, convenience can be improved.

(113) The above embodiment can be modified and implemented as follows. The above embodiment and following modifications can be implemented in combination with each other within a technically consistent range.

(114) In the above embodiment, the coupling length variable mechanism **100** is provided for the second link arm **82** constituting the sub-link **94** among the first and second link arms **81**, **82** constituting the second link mechanism **52**. However, the embodiment disclosed here is not limited thereto. The coupling length variable mechanism **100** may be provided in the first link arm **81** constituting the main link **95**, or the coupling length variable mechanism **100** may be provided in both the first and second link arms **81**, **82**. Even with such a configuration, it is possible to change the opening and closing trajectory **R2** of the rear door **32** based on the operation of the coupling length variable mechanism **100**. Accordingly, the interference between the first and second doors **41**, **42** in the vicinity of the fully closed position **P0** can be avoided. The first and second doors **41**, **42** can be opened and closed independently of each other without any order restriction.

(115) A configuration may be adopted in which the coupling length variable mechanism **100** is provided on the first link mechanism **51** side. Also in this case, the coupling length variable mechanism **100** may be provided at least one of the first and second link arms **71**, **72** forming the first link mechanism **51**. Accordingly, the opening and closing trajectory **R1** of the front door **31**

can be changed based on the operation of the coupling length variable mechanism **100**. The coupling length variable mechanism **100** may be provided in both the first and second link mechanisms **51**, **52**.

(116) That is, the coupling length variable mechanism **100** may be provided in any one of the first and second link arms **71**, **72** forming the first link mechanism **51** and the first and second link arms **81**, **82** forming the second link mechanism **52**. Accordingly, the interference between the first and second doors **41**, **42** in the vicinity of the fully closed position **P0** can be avoided. The first and second doors **41**, **42** can be opened and closed independently of each other without any order restriction.

(117) In the above embodiment, the coupling length variable mechanism **100** has a configuration as the joint link mechanism **110** in which the vehicle body side link **101** having the first rotary coupling point **X1** and the door side link **102** having the second rotary coupling point **X2** are rotatably coupled. However, the embodiment disclosed here is not limited thereto. The configuration of the coupling length variable mechanism **100** may be freely changed using a linear extension and contraction link mechanism or the like.

(118) In the above embodiment, when the rear door **32** is in the vicinity of the fully closed position **P0**, the opening and closing trajectory **R2** of the rear door **32** is changed to the linear trajectory **Rs**. However, the embodiment disclosed here is not limited thereto. The opening and closing trajectory **R2** after the change may not necessarily be the same linear trajectory **Rs** as in the above described embodiment. That is, the interference between the first and second doors **41**, **42** may be avoided in the vicinity of the fully closed position **P0**.

(119) In the above embodiment, the first door **41** is the front door **31** that is opened toward the vehicle front side based on the operation of the first link mechanism **51**. The second door **42** is the rear door **32** that is opened toward the vehicle rear side based on the operation of the second link mechanism **52**. However, the embodiment disclosed here is not limited thereto. The first door **41** may be the rear door **32**. The second door **42** may be the front door **31**. The first and second doors **41**, **42** may be back doors of the vehicle **1**, for example, may be provided at a location other than the door opening **3** that opens at the side surface **2s** of the vehicle body **2**, such as a rear hatch that opens at the rear of the vehicle **1**.

(120) In the above embodiment, the door opening **3** does not have a pillar structure at the central portion in the vehicle front-rear direction, and has a so-called pillarless structure in which the front opening **4** and the rear opening **5** are integrated. However, the embodiment disclosed here is not limited thereto, and may be applied to a structure in which the door opening **3** having a pillar structure at the central portion in the opening width direction, for example, the front opening **4** and the rear opening **5** are partitioned by a "B pillar".

(121) In the above embodiment, when the striker **175** is provided at the closing end portion **132** of the rear door **32**, the lock device **180** that engages with the striker **175** is provided at the closing end portion **131** of the front door **31**. However, the embodiment disclosed here is not limited thereto. The striker **175** may be provided at the closing end portion **131** of the front door **31**, and the lock device **180** that engages with the striker **175** may be provided at the closing end portion **132** of the rear door **32**.

(122) In the above embodiment, a pair of strikers **173**, **174** provided at the upper edge portion **3a** and the lower edge portion **3b** of the door opening **3** are provided. The upper lock **183** and the lower lock **184** that engage with the strikers **173**, **174** are provided at the closing end portion **131** of the front door **31**. However, the embodiment disclosed here is not limited thereto. Such a pair of upper and lower lock devices **180**, **180** may be provided at the closing end portion **132** of the rear door **32**.

(123) In the above embodiment, a pair of door side engagement portions **133**, **133** that are provided at the closing end portion **132** of the rear door **32** and a pair of vehicle body side engagement portions **134**, **134** that are provided at the upper edge portion **3a** and the lower edge portion **3b** of

the door opening **3** are provided. However, the embodiment disclosed here is not limited thereto, and the arrangement of the door side engagement portion **133** and the vehicle body side engagement portion **134** may be freely changed. For example, when the door opening **3** has a structure extending in the upper-lower direction such as the “B pillar”, the vehicle body side engagement portion **134** may be provided here. Further, the number of the door side engagement portions **133** and the vehicle body side engagement portions **134** may also be one, or three or more. (124) In the above embodiment, the door side engagement portion **133** includes the shaft-shaped engagement portion **151**, and the vehicle body side engagement portion **134** has the guide groove **152**. However, the embodiment disclosed here is not limited thereto. The door side engagement portion **133** may have the guide groove **152**. The vehicle body side engagement portion **134** may include the shaft-shaped engagement portion **151**.

(125) The door side engagement portion **133** and the vehicle body side engagement portion **134** as described above may be provided at the closing end portion **131** of the front door **31**. That is, the second door **42** supported by the second link mechanism **52**, which is the link mechanism **20** that does not include the coupling length variable mechanism **100**, may be provided with the door side engagement portion **133** and the vehicle body side engagement portion **134**. However, a more remarkable effect can be attained by adopting a configuration in which the door side engagement portion **133** and the vehicle body side engagement portion **134** are provided in the first door **41** supported by the first link mechanism **51**, which is the link mechanism **20** including the coupling length variable mechanism **100**.

(126) In the above embodiment, the first actuator **161** for opening and closing the first door **41** and the second actuator **162** for opening and closing the second door **42** are provided. However, the embodiment disclosed here is not limited thereto, and may be applied to a configuration in which one or both of the first and second doors **41**, **42** are manually opened and closed. The arrangement of the actuators **160** and a transmission structure of the driving force may also be freely changed.

(127) According to an aspect of this disclosure, a vehicle door device includes: a first link mechanism formed of first and second link arms having a first rotary coupling point with respect to a vehicle body and a second rotary coupling point with respect to a door of a vehicle; and a second link mechanism formed of the first and second link arms provided independently of the first and second link arms forming the first link mechanism. A first door supported by the first link mechanism and a second door supported by the second link mechanism are disposed side by side in a door opening formed in the vehicle, and thereby open and close independently in different directions based on operations of the first and second link mechanisms. At least one of the first and second link arms forming the first link mechanism and the first and second link arms forming the second link mechanism is provided with a coupling length variable mechanism that allows a coupling length between the first and second rotary coupling points to vary.

(128) According to the above configuration, based on operations of the first and second link mechanisms, the first and second doors are opened and closed while drawing an arc-shaped trajectory. That is, when the doors are opened and closed, the first and second doors move in an opening width direction of a door opening at an intermediate opening and closing position. Accordingly, it is possible to prevent a displacement amount of opening and closing when the doors protrude in an opening direction of the door opening in which the first and second doors are provided. For example, in the case of a door opening formed on a side surface of the vehicle body, the “opening width direction” is a vehicle front-rear direction, and the “opening direction” is a vehicle width direction. As a result, interference with an obstacle located in the opening direction of the door opening can be avoided, and a larger door opening amount can be secured.

(129) Further, when the door is in the vicinity of a fully closed position, the opening and closing trajectory of the door can be changed from the arc-shaped trajectory based on an operation of the coupling length variable mechanism provided in the link mechanism supporting the door. Accordingly, interference between the first and second doors in the vicinity of the fully closed

position can be avoided. The first and second doors can be opened and closed independently of each other without any order restriction.

(130) The vehicle door device according to the above aspect is preferably implemented such that, when the door supported by the link mechanism including the coupling length variable mechanism is in the vicinity of the fully closed position, the opening and closing trajectory of the door is changed to a linear trajectory along the opening width direction of the door opening based on the operation of the coupling length variable mechanism.

(131) According to the above configuration, in the vicinity of the fully closed position, the door supported by the link mechanism including the coupling length variable mechanism is opened and closed while drawing the linear trajectory along the opening direction width of the door opening. Accordingly, the first and second doors can be opened and closed independently of each other without any order restriction.

(132) In the vehicle door device according to the above aspect, it is preferable that the coupling length variable mechanism is provided on a second link mechanism side, and the coupling length variable mechanism is not provided on a first link mechanism side.

(133) That is, the opening and closing trajectory of the first door is not changed, so that it is possible to easily identify the opening and closing trajectory of the second door that does not interfere with the first door. Accordingly, high reliability can be secured with a simple configuration.

(134) In the vehicle door device according to the above aspect, it is preferable that the first door is a front door that is opened toward a vehicle front side based on an operation of the first link mechanism, and the second door is a rear door that is opened toward a vehicle rear side based on an operation of the second link mechanism.

(135) According to the above configuration, a so-called double opening front door and a so-called double opening rear door that are opened and closed in opposite directions can be disposed with respect to the door opening provided on the side surface of the vehicle body. Further, with respect to the front door and the rear door, it is possible to prevent the displacement amount of opening and closing when the doors protrude in the opening direction of the door opening, that is, to the outer side in the vehicle width direction. Accordingly, for example, it is possible to avoid the interference with an obstacle located in the opening direction of the door opening, such as a wall located in the vehicle width outer direction or a vehicle stopped adjacent thereto, and to secure a larger door opening amount. In addition, the front door and the rear door can be opened and closed independently of each other without any order restriction.

(136) The vehicle door device according to the above aspect preferably further includes: a door side engagement portion provided at a closing end portion of the door; and a vehicle body side engagement portion provided at a closing end portion of the door opening which the closing end portion of the door comes into contact with and separates from based on the opening and closing of the door. One side of the door side engagement portion and the vehicle body side engagement portion preferably includes a shaft-shaped engagement portion extending in an upper-lower direction of the vehicle. The other side of the door side engagement portion and the vehicle body side engagement portion preferably has a guide groove that includes a pair of side wall portions facing each other in an opening direction of the door opening and that extends in an opening and closing direction of the door. The shaft-shaped engagement portion is preferably disposed in the guide groove when the door in which the door side engagement portion and the vehicle body side engagement portion are engaged with each other is in the vicinity of a fully closed position.

(137) According to the above configuration, since the shaft-shaped engagement portion is disposed in the guide groove, displacement of the door provided with the door side engagement portion is restricted in the opening direction of the door opening. Accordingly, the door supported by the link mechanism can be stably supported even in the vicinity of the fully closed position where a distance between the first and second link arms forming the link mechanism is likely to be reduced

and the first and second link arms are likely to be linearly arranged.

(138) In the vehicle door device according to the above aspect, it is preferable that the door side engagement portion and the vehicle body side engagement portion are provided in the door that is supported by the link mechanism including the coupling length variable mechanism.

(139) According to the above configuration, in a state in which the door side engagement portion and the vehicle body side engagement portion are engaged with each other, the opening and closing trajectory of the door provided with the door side engagement portion changes from the arc-shaped trajectory to the linear trajectory based on the operation of the coupling length variable mechanism. Accordingly, even when the door on the other side which is paired with the door on one side provided with the door side engagement portion is in the fully closed state, the one door can be smoothly closed to the fully closed position and opened from the fully closed position.

(140) The vehicle door device according to the above aspect preferably further includes: a pair of the vehicle body side engagement portions provided at an upper edge portion and a lower edge portion of the door opening; and a pair of the door side engagement portions engaged with the vehicle body side engagement portions.

(141) According to the above configuration, it is possible to more stably support the door provided with the door side engagement portion in the vicinity of the fully closed position. Further, there is an advantage that the embodiment disclosed here can be applied to a so-called pillarless structure in which the closing end portion of the door opening does not have a structure extending in the upper-lower direction such as a “B pillar”. In the door opening, the vehicle body side engagement portion is disposed.

(142) In the vehicle door device according to the above aspect, it is preferable that a lock device configured to restrain the door at the fully closed position is not provided at the closing end portion of the door provided with the pair of door side engagement portions.

(143) According to the above configuration, even in the fully closed state, the closing end portion of the door provided with the pair of upper and lower door side engagement portions can be stably held based on an engagement force of the pair of door side engagement portions provided at the closing end portion and the vehicle body side engagement portions. Accordingly, it is possible to stably support the door at the fully closed position while simplifying the configuration.

(144) The vehicle door device according to the above aspect preferably further includes: a pair of strikers provided at an upper edge portion and a lower edge portion of the door opening; and a pair of lock devices provided at a closing end portion of the door and configured to engage with the strikers to restrain the door at a fully closed position.

(145) According to the above configuration, the door provided with the pair of upper and lower lock devices can be more stably restrained at the fully closed position. Further, there is an advantage that the embodiment disclosed here can be applied to a so-called pillarless structure in which the closing end portion of the door opening does not have a structure extending in the upper-lower direction such as a “B pillar”. In the door opening, the striker is to be disposed.

(146) The vehicle door device according to the above aspect preferably further includes: a striker provided at a closing end portion of one of the first and second doors; and a lock device provided at a closing end portion of the other one of the first and second doors and configured to engage with the striker to restrain the first and second doors at a fully closed position.

(147) According to the above configuration, even when the door opening has the so-called pillarless structure in which the closing end portions thereof do not have the structure extending in the upper-lower direction such as the “B pillar”, the first and second doors provided side by side in the opening width direction of the door opening can be stably restrained at the fully closed position.

(148) The vehicle door device according to the above aspect preferably further includes: a first actuator configured to apply a driving force to the first link mechanism to open and close the first door; and a second actuator configured to apply a driving force to the second link mechanism to open and close the second door.

(149) According to the above configuration, convenience can be improved.

(150) In the vehicle door device according to the above aspect, it is preferable that the first door and the second door are disposed at a fully closed position in a state in which closing end portion tip ends of the first door and the second door overlap each other in an opening direction of the door opening.

(151) According to this disclosure, it is possible to secure a larger door opening amount by reducing a displacement amount of opening and closing when the doors protrude in the opening direction of the door opening.

(152) The principles, preferred embodiment and mode of operation of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. Further, the embodiments described herein are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others, and equivalents employed, without departing from the spirit of the present invention. Accordingly, it is expressly intended that all such variations, changes and equivalents which fall within the spirit and scope of the present invention as defined in the claims, be embraced thereby.

## Claims

1. A vehicle door device comprising: a first link mechanism formed of first and second link arms having a first rotary coupling point with respect to a vehicle body and a second rotary coupling point with respect to a door of a vehicle; a second link mechanism formed of the first and second link arms provided independently of the first and second link arms forming the first link mechanism; a door side engagement portion provided at a closing end portion of the door; a vehicle body side engagement portion provided at a closing end portion of the door opening which the closing end portion of the door comes into contact with and separates from based on the opening and closing of the door; a pair of the vehicle body side engagement portions provided at an upper edge portion and a lower edge portion of the door opening; and a pair of the door side engagement portions configured to engage with the vehicle body side engagement portions, wherein a first door supported by the first link mechanism and a second door supported by the second link mechanism are disposed side by side in a door opening formed in the vehicle, and thereby open and close independently in different directions based on operations of the first and second link mechanisms, at least one of the first and second link arms forming the first link mechanism and the first and second link arms forming the second link mechanism is provided with a coupling length variable mechanism that allows a coupling length between the first and second rotary coupling points to vary, one side of the door side engagement portion and the vehicle body side engagement portion includes a shaft-shaped engagement portion extending in an upper-lower direction of the vehicle, the other side of the door side engagement portion and the vehicle body side engagement portion has a guide groove that includes a pair of side wall portions facing each other in an opening direction of the door opening and that extends in an opening and closing direction of the door, and the shaft-shaped engagement portion is disposed in the guide groove when the door in which the door side engagement portion and the vehicle body side engagement portion are engaged with each other is in the vicinity of a fully closed position.

2. The vehicle door device according to claim 1, wherein when the door including the coupling length variable mechanism is in the vicinity of a fully closed position, an opening and closing trajectory of the door is changed to a linear trajectory along an opening width direction of the door opening based on an operation of the coupling length variable mechanism.

3. The vehicle door device according to claim 1, wherein the coupling length variable mechanism is provided on a second link mechanism side, and the coupling length variable mechanism is not provided on a first link mechanism side.

4. The vehicle door device according to claim 1, wherein the first door is a front door configured to be opened toward a vehicle front side based on an operation of the first link mechanism, and the second door is a rear door configured to be opened toward a vehicle rear side based on an operation of the second link mechanism.
  5. The vehicle door device according to claim 1, wherein the door side engagement portion and the vehicle body side engagement portion are provided in the door including the coupling length variable mechanism.
  6. The vehicle door device according to claim 1, wherein a lock device configured to restrain the door at a fully closed position is not provided at the closing end portion of the door provided with the pair of door side engagement portions.
  7. The vehicle door device according to claim 1, further comprising: a pair of strikers provided at an upper edge portion and a lower edge portion of the door opening; and a pair of lock devices provided at a closing end portion of the door and configured to engage with the strikers to restrain the door at a fully closed position.
  8. The vehicle door device according to claim 1, further comprising: a striker provided at a closing end portion of one of the first and second doors; and a lock device provided at a closing end portion of the other one of the first and second doors and configured to engage with the striker to restrain the first and second doors at a fully closed position.
  9. The vehicle door device according to claim 1, further comprising: a first actuator configured to apply a driving force to the first link mechanism to open and close the first door; and a second actuator configured to apply a driving force to the second link mechanism to open and close the second door.
  10. The vehicle door device according to claim 1, wherein the first door and the second door are disposed at a fully closed position in a state in which closing end portion tip ends of the first door and the second door overlap each other in an opening direction of the door opening.
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