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(72) Inventors:
• **MAKIHIRA, Ikuo**
Chiyoda-ku, Tokyo 102-0093 (JP)
• **IZUTSU, Masayuki**
Chiyoda-ku, Tokyo 102-0093 (JP)
• **TAKAGI, Kouki**
Shibuya-ku, Tokyo (JP)
(74) Representative: **Grünecker Patent- und Rechtsanwälte PartG mbB**
Leopoldstraße 4
80802 München (DE)

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(71) Applicant: **Nabtesco Corporation**
Tokyo 102-0093 (JP)

(54) **PLUG DOOR DEVICE**

(57) A plug door device (1) includes an upper swing arm (31), a lower swing arm (32), an upper pinion (33) attached to the upper swing arm (31), an upper rack (35) meshed with the upper pinion (33), a lower pinion (34) attached to the lower swing arm (32), a lower rack (36) meshed with the lower pinion (34), an arm connection shaft (40) connecting the upper swing arm (31) and the lower swing arm (32), and a pinion connection shaft (50) connecting the upper pinion (33) and the lower pinion (34). The arm connection shaft (40) includes a first universal joint (44) and a second universal joint (45). The pinion connection shaft (50) includes a third universal joint (54) and a fourth universal joint (55).

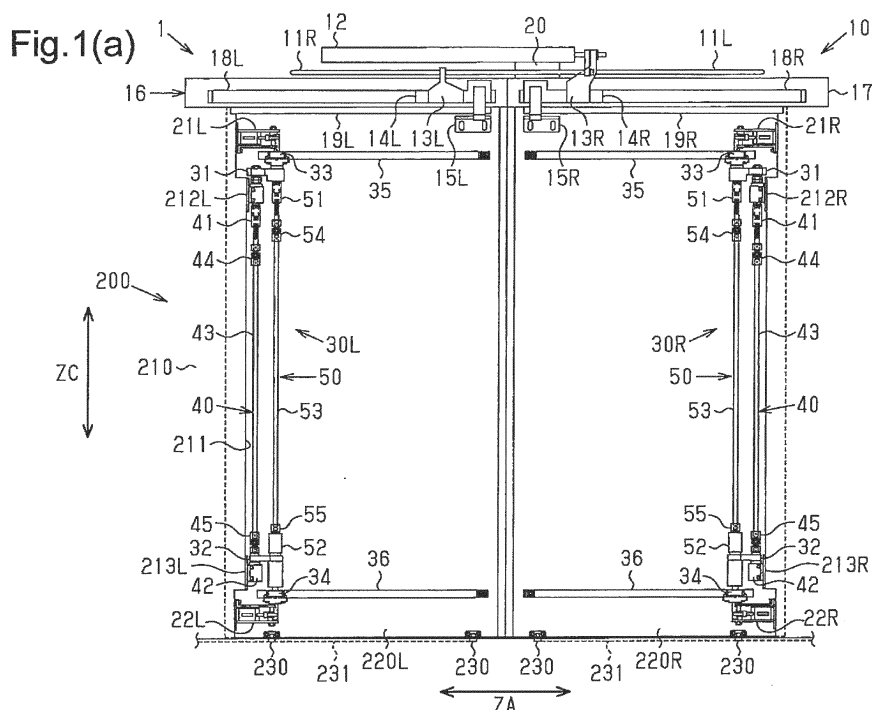
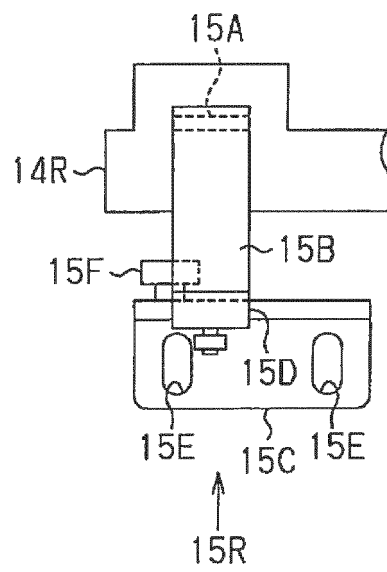


Fig.1(b)



Description

[0001] The present invention relates to a plug door device.

[0002] A railway vehicle is provided with, for example, a plug door device. The plug door device opens and closes a door provided at an entrance of a vehicle body in the railway vehicle in a vehicle front-rear direction while moving the door in a vehicle width direction. Japanese Laid-Open Patent Publication No. 6-262945 describes one example of a plug door device that includes a stabilizer to prevent upper and lower portions of a door from being displaced relative to each other in a vehicle width direction and a vehicle front-rear direction when the door opens or closes.

[0003] An example of a plug door device including a stabilizer will now be described with reference to Figs. 14 and 15.

[0004] As shown in Fig. 14, a plug door device 300 includes a feed screw type drive unit 310 serving as a drive source which opens and closes a single panel door 400, a stabilizer 320 which is provided to connect an upper portion and a lower portion of the door 400 to each other, and a rack and pinion mechanism 330 which guides the movement of the door 400 in a vehicle front-rear direction.

[0005] The stabilizer 320 includes an upper swing arm 321 which is arranged on the upper portion of the door 400 and rotated in accordance with the movement of the door 400 in the vehicle width direction, a lower swing arm 322 which is arranged on the lower portion of the door 400 and rotated in accordance with the movement of the door 400 in the vehicle width direction, and a connection shaft 323 which connects the upper swing arm 321 and the lower swing arm 322 to each other. An upper portion of the connection shaft 323 is inserted into a distal end portion of the upper swing arm 321, and a lower portion of the connection shaft 323 is inserted into a distal end portion of the lower swing arm 322. In this way, the distal end portion of the upper swing arm 321 and the distal end portion of the lower swing arm 322 are connected to each other by the connection shaft 323. Thus, when the door 400 moves in the vehicle width direction, the upper swing arm 321 and the lower swing arm 322 rotate synchronously. Accordingly, the upper portion and the lower portion of the door 400 move synchronously in the vehicle width direction.

[0006] The rack and pinion mechanism 330 includes an upper rack 331 which is provided on the upper portion of the door 400, an upper pinion 332 which is provided on the distal end of the upper swing arm 321, a lower rack 333 which is provided on the lower portion of the door 400, and a lower pinion 334 which is provided on the distal end of the lower swing arm 322. The upper rack 331 and the lower rack 333 have the same construction, and the upper pinion 332 and the lower pinion 334 have the same construction. In addition, the upper pinion 332 is attached to an upper end portion of the connection

shaft 323 protruding upward from the upper swing arm 321, and the lower pinion 334 is attached to a lower end portion of the connection shaft 323 protruding downward from the lower swing arm 322. That is, the connection shaft 323 is connected to the upper pinion 332 and the lower pinion 334. According to this construction, when the door 400 moves in the vehicle front-rear direction, rotation of the upper pinion 332 is transmitted to the lower pinion 334 via the connection shaft 323. Thus, the upper pinion 332 and the lower pinion 334 rotate synchronously. The upper rack 331 and the upper pinion 332 respectively mesh with the lower rack 333 and the lower pinion 334 in the same manner. This synchronously moves the upper portion and the lower portion of the door 400 in the vehicle front-rear direction.

[0007] As shown in Fig. 15, the door 400 is inclined relative to the vertical direction, and the lower portion of the door 400 is curved. Accordingly, the position of the upper swing arm 321 of the stabilizer 320 in the vehicle width direction is separated from the position of the lower swing arm 322 in the vehicle width direction. Therefore, rotation axis of the upper swing arm 321 and rotation axis of the lower swing arm 322 are inclined relative to the vertical direction so as to be located outward in the vehicle width direction at lower positions.

[0008] Referring to Fig. 15, when the door 400 moves outward in the vehicle width direction, the upper swing arm 321 and the lower swing arm 322 need to pull the door 400.

[0009] Therefore, the weight of the door 400 acts as a resistance against the rotations of the upper swing arm 321 and the lower swing arm 322. This may hinder smooth opening of the door 400.

[0010] This problem is not limited to a single panel door and may also occur with a double panel door. Moreover, in a case where the rotation axis of the upper swing arm and the rotation axis of the lower swing arm are inclined relative to the vertical direction so as to be located inward in the vehicle width direction at lower positions, when each swing arm is rotated to move the door to a fully closed position, the weight of the door acts as a resistance on each swing arm. This may hinder smooth closing of the door.

[0011] It is an object of the present invention to provide a plug door device that smoothly opens and closes a door.

[1] A plug door device according to one aspect of the present invention includes a first swing arm, a second swing arm spaced apart from the first swing arm in a height direction of a door, a first pinion attached to a portion of the first swing arm separated from a rotation axis of the first swing arm, a first rack attached to the door and meshed with the first pinion, a second pinion attached to a portion of the second swing arm separated from a rotation axis of the second swing arm, a second rack attached to the door and meshed with the second pinion, an arm connec-

tion shaft, and a pinion connection shaft. The arm connection shaft includes a first arm shaft connected to the first swing arm and having an axis coinciding with the rotation axis of the first swing arm, a second arm shaft connected to the second swing arm and having an axis coinciding with the rotation axis of the second swing arm, and a third arm shaft connecting the first arm shaft and the second arm shaft. The arm connection shaft rotates integrally with the first swing arm and the second swing arm to synchronize rotation of the first swing arm and rotation of the second swing arm. The pinion connection shaft includes a first pinion shaft connected to the first pinion and having an axis coinciding with a rotation axis of the first pinion, a second pinion shaft connected to the second pinion and having an axis coinciding with a rotation axis of the second pinion, and a third pinion shaft connecting the first pinion shaft and the second pinion shaft. The pinion connection shaft rotates integrally with the first pinion and the second pinion to synchronize rotation of the first pinion and rotation of the second pinion. The arm connection shaft includes a first universal joint, which connects the first arm shaft and the third arm shaft, and a second universal joint, which connects the second arm shaft and the third arm shaft. The pinion connection shaft includes a third universal joint, which connects the first pinion shaft and the third pinion shaft, and a fourth universal joint, which connects the second pinion shaft and the third pinion shaft.

[0012] According to this construction, by inclining the third arm shaft relative to the first arm shaft and the second arm shaft with the first universal joint and the second universal joint, axial directions of the first arm shaft and the second arm shaft are adjustable in the vertical direction. Accordingly, for example, even in a case where the door has a curved shape and the position of the first swing arm in the vehicle width direction is thereby separated from the position of the second swing arm in the vehicle width direction, it is possible to prevent the rotation axes of the first swing arm and the second swing arm from being inclined relative to the vertical direction by inclining the third arm shaft relative to the vertical direction. Thus, the weight of the door does not act as a resistance when the first swing arm and the second swing arm rotate. This enables smooth movement of the door in the vehicle width direction.

[0013] In a case where an axial direction of the first pinion shaft is inclined relative to the vertical direction, if the position of the first pinion in the vertical direction with respect to the first rack were to be separated from a preset position due to machining errors or assembly errors of the first rack and the first pinion, the teeth of the first pinion would be meshed with the teeth of the first rack at an inappropriate position in a direction in which the first pinion and the first rack face each other. As a result, the meshing force between the first rack and the first pinion

would be excessively large or small, and the first pinion will not rotate smoothly on the first rack. Similarly, in a case where an axial direction of the second pinion shaft is inclined relative to the vertical direction, the second pinion will not rotate smoothly on the second rack.

[0014] In this regard, according to the plug door device, the third universal joint and the fourth universal joint incline the third pinion shaft relative to the first pinion shaft and the second pinion shaft to adjust the axial directions of the first pinion shaft and the second pinion shaft relative to the vertical direction. Accordingly, even when the position of the first pinion in the vertical direction with respect to the first rack differs from the preset position due to machining errors or assembly errors of the first rack and the first pinion, the teeth of the first pinion are meshed with the teeth of the first rack at an appropriate position in the direction in which the first pinion and the first rack face each other. Thus, the first pinion is meshed with the first rack with an appropriate force. Similarly, the second pinion is meshed with the second rack with an appropriate force. As a result, for example, even in a case where the door has a curved shape and the position of the first pinion in the vehicle width direction is thereby separated from the position of the second pinion in the vehicle width direction, the first pinion smoothly rotates smoothly on the first rack and the second pinion rotates smoothly on the second rack. Thus, the door smoothly opens and closes.

[2] The plug door device according to another aspect of the present invention further includes an arm adjustment mechanism, which is configured to adjust the distance between the first swing arm and the second swing arm, and a pinion adjustment mechanism, which is configured to adjust the distance between the first pinion and the second pinion.

[0015] According to this construction, the arm adjustment mechanism adjusts the distance between the first swing arm and the second swing arm to adjust the position of the first swing arm and the position of the second swing arm in correspondence with the position of the door relative to the vehicle body.

[0016] When the position of the door relative to the vehicle body is changed, the positions of the first rack and the second rack, which are attached to the door, relative to the vehicle body are changed. Accordingly, the pinion adjustment mechanism changes the distance between the first pinion and the second pinion to arrange the first pinion at a position at which the first pinion meshes with the first rack and arrange the second pinion at a position at which the second pinion meshes with the second rack.

[3] In the plug door device according to another aspect of the present invention, the arm adjustment mechanism includes a first male threaded portion, which is provided on the first arm shaft, and a first nut, which is fastened to the first male threaded por-

tion. The first nut is configured to change the position of the first swing arm by moving in an axial direction of the first male threaded portion.

This construction changes the distance between the first swing arm and the second swing arm in accordance with the fastened amount of the first nut. Therefore, the distance between the first swing arm and the second swing arm is adjusted in a stepless manner.

[4] In the plug door device according to another aspect of the present invention, the pinion adjustment mechanism includes a second male threaded portion, which is provided on the second pinion shaft, and a second nut, which is fastened to the second male threaded portion. The second nut is configured to change the position of the second pinion by moving in an axial direction of the second male threaded portion.

This construction changes the distance between the first pinion and the second pinion in accordance with the fastened amount of the second nut. Therefore, the distance between the first pinion and the second pinion is adjusted in a stepless manner.

[5] In the plug door device according to another aspect of the present invention, at least one of the first arm shaft and the first pinion shaft includes a first connection shaft and a second connection shaft, which are separately formed, and a connection member connected to the first connection shaft to be non-rotatable to the first connection shaft and movable relative to the first connection shaft and connected to the second connection shaft to be non-rotatable to the second connection shaft and non-movable relative to the second connection shaft.

This construction restricts relative rotation between the first connection shaft and the second connection shaft allows the axial length of the first arm shaft (first pinion shaft) to be easily changed.

[6] The plug door device according to another aspect of the present invention further includes an attachment member configured to attach the first arm shaft to a vehicle body. The attachment member is configured to be attached to a fixing member provided on the vehicle body and including a first vertical serration extending in the vertical direction. The attachment member includes a second vertical serration configured to be meshed with the first vertical serration.

According to this construction, the second vertical serration of the attachment member meshes with the first vertical serration of the fixing member. This restricts inclination of the attachment member relative to the fixing member. Accordingly, the arm connection shaft inserted into the attachment member is not inclined relative to the fixing member. This further restricts inclination of the rotation axes of the first swing arm and the second swing arm relative to the vertical direction.

[7] In the plug door device according to another aspect of the present invention, the first pinion and the first rack are arranged on an upper portion of the door. The second pinion and the second rack are arranged on a lower portion of the door.

[0017] For example, if a rack and pinion mechanism were to be located at the middle of the door in the height direction, this would lower the aesthetic appearance of the door. In this regard, the above aspect [7] does not arrange the rack and pinion mechanism at the middle of the door and thereby improves the aesthetic appearance of the door.

[0018] The plug door device according to the present invention smoothly opens and closes the door.

[0019] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

[0020] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 (a) is a front view of a plug door device of one embodiment;

Fig. 1(b) is an enlarged view of a door hanger;

Fig. 2(a) is a plan view of a rail mechanism of the plug door device of Fig. 1 (a) when a door is located at a fully closed position;

Fig. 2(b) is a plan view of the rail mechanism when the door is located at a fully open position;

Fig. 3(a) is a side view of the plug door device when the door is located at the fully closed position;

Fig. 3(b) is a side view of the plug door device when the door is located at the fully open position;

Fig. 4(a) is a plan view of an upper swing arm and surroundings thereof;

Fig. 4(b) is a front view of the upper swing arm and surroundings thereof;

Fig. 4(c) is a side view of a support arm;

Fig. 4(d) is a side view showing the relationship between the door and an upper pinion and surroundings thereof;

Fig. 5 is a cross-sectional view taken along line 5-5 in Fig. 4(a);

Fig. 6 is an exploded perspective view showing an attachment structure for an attachment member and an upper fixing member;

Fig. 7 is a partial front view showing an arm connection shaft and a pinion connection shaft;

Fig. 8(a) is a plan view of a lower swing arm and surroundings thereof;

Fig. 8(b) is a front view of the lower swing arm and surroundings thereof;

Fig. 8(c) is a side view showing the relationship between the door and a lower pinion and surroundings

thereof;

Fig. 9 is a cross-sectional view taken along line 9-9 in Fig. 8(a);

Fig. 10(a) is a plan view showing the relationship between the upper swing arm and the door;

Fig. 10(b) is a plan view showing the relationship between the lower swing arm and the door;

Fig. 10(c) is a plan view showing the relationship between a rolling body of the door and a rail of a vehicle body;

Fig. 11(a) is a plan view showing the relationship between an upper retracting device and the door;

Fig. 11(b) is a plan view showing the relationship between a lower retracting device and the door;

Fig. 12(a) is a side view of a lock cylinder and the lower swing arm when the lock cylinder is locked;

Fig. 12(b) is a side view of the lock cylinder and the lower swing arm when the lock cylinder is unlocked;

Fig. 13 is a flowchart showing the procedure for attaching the plug door device;

Fig. 14 is a front view of a conventional plug door device; and

Fig. 15 is a side view of the plug door device of Fig. 14.

[0021] One embodiment of a plug door device will now be described with reference to the drawings.

[0022] As shown in Fig. 1(a), a plug door device 1 opens and closes double-slide doors 220R and 220L provided on a vehicle body 210 of a railway vehicle 200. In a lower end portion of each of the doors 220R and 220L, rolling bodies 230 are provided at two locations spaced apart in a front-rear direction (hereinafter, referred to as a "front-rear direction ZA") of the vehicle 200. The number of rolling bodies 230 can be arbitrarily set. Each rolling body 230 is slidably housed in a rail 231 which is provided in the vehicle body 210. As shown by two-dot chain lines of Figs. 3(a) and 3(b), the door 200R has a shape in which a lower portion of the door 220R is bent toward an inside of the vehicle 200 in a vehicle width direction (hereinafter, referred to as a "the vehicle width direction ZB") of the vehicle 200. The door 220L is similar to the door 220R in construction and shape. In addition, the plug door device 1 can be applied to a cantilever door.

[0023] As shown in Fig. 1(a), the plug door device 1 includes a drive mechanism 10 serving as a drive source which opens and closes the doors 220R and 220L. The drive mechanism 10 is provided on an upper portion of the vehicle body 210. The drive mechanism 10 includes two rods 11R and 11L which extend in the front-rear direction ZA, a drive cylinder 12 which moves the rods 11R and 11L in the front-rear direction ZA with pneumatic pressure, a rail mechanism 16 for guiding movements of the doors 220R and 220L in the vehicle width direction ZB and the front-rear direction ZA, and a pulling mechanism 20 which moves the rods 11R and 11L in opposite directions. In addition, in the drive mechanism 10, the two rods 11R and 11L may be moved by a feed screw

mechanism driven by an electric motor instead of the drive cylinder 12.

[0024] The two rods 11R and 11L are arranged spaced apart in the vehicle width direction ZB. A door hanger 15R is connected to the rod 11R by a connection member 13R and a slide member 14R. A door hanger 15L is connected to the rod 11L by a connection member 13L and a slide member 14L.

[0025] The connection member 13R connects the rod 11R and the slide member 14R. The slide member 14R extends in the front-rear direction ZA. As shown in Fig. 1(b), the door hanger 15R is attached rotatably about a rotary shaft 15A, which is located at a position on the slide member 14R separated from the connection member 13R (refer to Fig. 1(a)) in the front-rear direction ZA. The door hanger 15R includes an arm 15B which is supported by the rotary shaft 15A, an attachment portion 15C which is attached to the door 220R and horizontally movable in the vehicle width direction ZB, and a connection portion 15D which is rotatably connected to the arm 15B and pivotally connected to the attachment portion 15C. For example, the attachment portion 15C is attached to the door 220R by a bolt (not shown). An elongated hole 15E into which the bolt is inserted is formed in the attachment portion 15C. In the elongated hole 15E, a height direction (hereinafter, referred to as a "height direction ZC") of the vehicle 200 is a longitudinal direction of the elongated hole 15E. In the present embodiment, the height direction ZC coincides with the vertical direction. A rolling body 15F which is rotatable around rotation axis along the height direction ZC is attached to an upper surface of the attachment portion 15C. Moreover, the connection member 13L, the slide member 14L, and the door hanger 15L are respectively similar in construction to the connection member 13R, the slide member 14R, and the door hanger 15R.

[0026] As shown in Fig. 1(a), the rail mechanism 16 includes a support member 17 which is attached to the vehicle body 210. A length of the support member 17 in the front-rear direction ZA is greater than a width of an entrance 211 in the front-rear direction ZA. Linear first rails 18R and 18L extending in the front-rear direction ZA are attached to a front surface of the support member 17, and second rails 19R and 19L are attached to a lower surface of the support member 17.

[0027] The first rails 18R and 18L are open to the front side of the support member 17. The slide member 14R is movably attached to the first rail 18R in the front-rear direction ZA, and the slide member 14L is movably attached to the first rail 18L in the front-rear direction ZA.

[0028] The second rails 19R and 19L are open downward (refer to Figs. 3(a) and 3(b)). As shown in Figs. 2(a) and 2(b), each of the second rails 19R and 19L includes an inclined portion 19A, which is inclined to be bent outward in the vehicle width direction ZB from the center of the entrance 211 toward an end of the entrance 211 in the front-rear direction ZA, and a linear portion 19B, which extends in the front-rear direction ZA from an end of the

inclined portion 19A in the front-rear direction ZA. In the second rail 19R, the rolling body 15F of the door hanger 15R is slidably accommodated in the second rail 19R. In the second rail 19L, the rolling body 15F of the door hanger 15L is slidably accommodated in the second rail 19L.

[0029] The pulling mechanism 20 is arranged between the two rods 11R and 11L in the vehicle width direction ZB. An example of the pulling mechanism 20 includes pinion teeth (not shown) that mesh with rack teeth (not shown) which are provided on the two rods 11R and 11L. In the pulling mechanism 20, as the rod 11R is moved by the drive cylinder 12, the pinion teeth meshed with the rack teeth of the rod 11R rotate, and the rod 11L meshed with the pinion teeth moves in a direction opposite to the movement direction of the rod 11R.

[0030] As shown in Fig. 1(a), the plug door device 1 includes stabilizers 30R and 30L which prevent an upper portion and a lower portion of each of the doors 220R and 220L from being displaced relative to each other when the doors 220R and 220L are opened and closed. The stabilizers 30R and 30L are provided on both sides of the entrance 211 in the front-rear direction ZA.

[0031] The stabilizer 30R includes an upper swing arm 31 which is an example of a first swing arm arranged on an upper portion of the door 220R, a lower swing arm 32 which is an example of a second swing arm arranged on a lower portion of the door 220R, and an arm connection shaft 40 which connects the upper swing arm 31 and the lower swing arm 32 to each other. In addition, the stabilizer 30R includes an upper pinion 33 which is an example of a first pinion provided on the upper swing arm 31, a lower pinion 34 which is an example of a second pinion provided on the lower swing arm 32, and a pinion connection shaft 50 which connects the upper pinion 33 and the lower pinion 34 to each other.

[0032] The arm connection shaft 40 includes a first arm shaft 41 connected to the upper swing arm 31 and having an axis coinciding with the rotation axis of the upper swing arm 31, a second arm shaft 42 connected to the lower swing arm 32 and having an axis coinciding with the rotation axis of the lower swing arm 32, and a third arm shaft 43 connecting the first arm shaft 41 and the second arm shaft 42. Further, the arm connection shaft 40 includes a first universal joint 44 which connects the first arm shaft 41 and the third arm shaft 43 so as to be integrally rotatable with each other, and a second universal joint 45 which connects the second arm shaft 42 and the third arm shaft 43 so as to be integrally rotatable with each other. An example of each of the first universal joint 44 and the second universal joint 45 is a Cardan joint. Each of the first universal joint 44 and the second universal joint 45 may be a Rzeppa joint or a constant velocity joint instead of the Cardan joint.

[0033] As shown in Figs. 3(a) and 3(b), the first arm shaft 41 includes a first connection shaft 41A which is connected to the first universal joint 44 and a second connection shaft 41B which is connected to an upper end portion of the first connection shaft 41A. The first con-

nection shaft 41A and the second connection shaft 41B are integrally rotatable. In this way, the first arm shaft 41, the second arm shaft 42, and the third arm shaft 43 are integrally rotatable. The arm connection shaft 40 thereby synchronizes the rotation of the upper swing arm 31 and the rotation of the lower swing arm 32.

[0034] The upper swing arm 31 and the lower swing arm 32 are attached to the door 220R in conformance with the shape of the door 220R. Accordingly, the lower swing arm 32 is arranged inside the upper swing arm 31 in the vehicle width direction ZB. The first arm shaft 41 and the second arm shaft 42 extend in the height direction ZC (vertical direction). The third arm shaft 43 can be inclined toward the first arm shaft 41 by the first universal joint 44 and inclined toward the second arm shaft 42 by the second universal joint 45. Further, the third arm shaft 43 is inclined so as to be located outward in the vehicle width direction ZB at upper positions.

[0035] As shown in Fig. 3(b), the upper pinion 33 is attached to a portion of the upper swing arm 31 which is separated from the rotation axis of the upper swing arm 31, for example, a distal end portion of the upper swing arm 31. As shown in Fig. 1(a), an upper rack 35 extending in the front-rear direction ZA is attached to an upper portion of the door 220R facing the upper pinion 33 in the vehicle width direction ZB. The upper pinion 33 and the upper rack 35 mesh with each other.

[0036] As shown in Fig. 3(b), the lower pinion 34 is attached to a portion of the lower swing arm 32 which is separated from the rotation axis of the lower swing arm 32, for example, a distal end portion of the lower swing arm 32. As shown in Fig. 1(a), a lower rack 36 extending in the front-rear direction ZA is attached to a lower portion of the door 220R facing the lower pinion 34 in the vehicle width direction ZB. The lower pinion 34 and the lower rack 36 mesh with each other. In addition, the upper pinion 33 and the lower pinion 34 have the same number of teeth and the same shape, and the upper rack 35 and the lower rack 36 have the same number of teeth and the same shape.

[0037] The pinion connection shaft 50 includes a first pinion shaft 51 connected to the upper pinion 33 and having an axis coinciding with the rotation axis of the upper pinion 33, a second pinion shaft 52 connected to the lower pinion 34 and having an axis coinciding with the rotation axis of the lower pinion 34, and a third pinion shaft 53 connecting the first pinion shaft 51 and the second pinion shaft 52. Moreover, the pinion connection shaft 50 includes a third universal joint 54, which connects the first pinion shaft 51 and the third pinion shaft 53 in an integrally rotatable manner, and a fourth universal joint 55, which connects the second pinion shaft 52 and the third pinion shaft 53 in an integrally rotatable manner. An example of each of the third universal joint 54 and the fourth universal joint 55 is a Cardan joint. Each of the third universal joint 54 and the fourth universal joint 55 may be a Rzeppa joint or a constant velocity joint instead of the Cardan joint.

[0038] As shown in Fig. 3(b), the first pinion shaft 51 includes a first connection shaft 51A, which is connected to the third universal joint 54, and a second connection shaft 51B, which is connected to an upper end portion of the first connection shaft 51A. The first connection shaft 51A and the second connection shaft 51B are integrally rotatable. In this way, the first pinion shaft 51, the second pinion shaft 52, and the third pinion shaft 53 are integrally rotatable. Thus, the pinion connection shaft 50 synchronizes the rotation of the upper pinion 33 and the rotation of the lower pinion 34.

[0039] As shown in Figs. 1(b), 3(a), and 3(b), the plug door device 1 includes retracting devices 21R, 21L, 22R, and 22L which retract the pinion connection shafts 50 of the stabilizers 30R and 30L inward in the vehicle width direction ZB. In addition, the plug door device 1 includes lock cylinders 23R and 23L (lock cylinder 23L not shown in Figs. 3(a) and 3(b), refer to Figs. 12(a) and 12(b)) which restrict rotation about the rotation axis of the lower swing arm 32 of the stabilizers 30R and 30L. The retracting devices 21R and 21L are attached to the vehicle body 210 above the upper pinion 33 and the upper rack 35. The retracting devices 22R and 22L are attached to the vehicle body 210 below the lower pinion 34 and the lower rack 36. The retracting devices 21R and 21L have arms 21A for retracting the upper end portions of the pinion connection shafts 50 of the stabilizers 30R and 30L inward in the vehicle width direction ZB. The retracting devices 22R and 22L have arms 22A for retracting the lower end portions of the pinion connection shafts 50 of the stabilizers 30R and 30L inward in the vehicle width direction ZB.

[0040] The stabilizer 30R will now be described in detail with reference to Figs. 1(a), 1(b), and 4(a) to 11(b). The stabilizer 30L has the same construction as the stabilizer 30R.

[0041] Figs. 4(a) to 4(d) and 5 show the upper portion of the stabilizer 30R, particularly, the upper swing arm 31 and surroundings thereof.

[0042] As shown in Fig. 4(b), the upper swing arm 31 includes an arm support portion 31A which supports the first arm shaft 41 of the arm connection shaft 40 in a non-rotatable manner, a pinion support portion 31B which supports the first pinion shaft 51 of the pinion connection shaft 50 in a rotatable manner, and a connection portion 31C which connects the arm support portion 31A and the pinion support portion 31B. The arm support portion 31A is tubular and has an insertion hole 31D (refer to Fig. 5) into which the first arm shaft 41 can be inserted, and the pinion support portion 31B is tubular and has an insertion hole 31E (refer to Fig. 5) into which the first pinion shaft 51 can be inserted. The dimension of the pinion support portion 31B in the height direction ZC is larger than the dimension of the arm support portion 31A in the height direction ZC.

[0043] The second connection shaft 51B of the first pinion shaft 51 projects toward two opposite sides in the height direction ZC with from the pinion support portion

31B. The upper pinion 33 is attached to a portion of the second connection shaft 51B above the pinion support portion 31B in a non-rotatable manner. A support arm 60 is attached to a portion of the second connection shaft 51B between the pinion support portion 31B and the upper pinion 33 in the height direction ZC.

[0044] As shown in Fig. 4(a), the support arm 60 extends in a direction orthogonal to the second connection shaft 51B. Two first rolling bodies 61, which are arranged spaced apart in the front-rear direction ZA, and a second rolling body 62, which is arranged between the two first rolling bodies 61, are attached to a distal end portion of the support arm 60. The two first rolling bodies 61 are each rotatable about its rotation axis in a direction extending in the height direction ZC, and the second rolling body 62 is rotatable about its rotation axis in a direction orthogonal to the height direction ZC. As shown in Fig. 4(c), an upper end portion of the second rolling body 62 is located above upper end portions of the two first rolling bodies 61. As shown in Fig. 4(d), the two first rolling bodies 61 and the second rolling body 62 are accommodated in an upper rail 221 which is provided on a rear side (the outside in the vehicle width direction ZB) of the upper rack 35 of the door 220R. The upper rail 221 extends in the front-rear direction ZA and is open downward. The two first rolling bodies 61, which is in contact with one of the two side walls of the upper rail 221 in the vehicle width direction ZB, and the second rolling body 62, which is in contact with an upper wall of the upper rail 221, supports the door 220R,

[0045] As shown in Fig. 5, the second connection shaft 51B of the first pinion shaft 51 is supported by a first rolling bearing 63 and a second rolling bearing 64 to be rotatable relative to the upper swing arm 31. The first rolling bearing 63 is a bearing integrally combining a thrust bearing 63A and a radial bearing 63B. The thrust bearing 63A is arranged on an upper surface of the pinion support portion 31B, and the radial bearing 63B is arranged in an upper end portion of the insertion hole 31E of the pinion support portion 31B. The second rolling bearing 64 is attached to a lower end portion of the insertion hole 31E of the pinion support portion 31B. The support arm 60 is supported by a third rolling bearing 65 to be rotatable about the first pinion shaft 51. The support arm 60 is supported by the thrust bearing 63A of the first rolling bearing 63 in the height direction ZC. The thrust bearing 63A and the radial bearing 63B may be formed separately in the first rolling bearing 63. The thrust bearing 63A, the radial bearing 63B, the second rolling bearing 64, and the third rolling bearing 65 may each be a ball bearing or a roller bearing.

[0046] As shown in Fig. 4(b), the portion of the second connection shaft 41B of the first arm shaft 41 below the arm support portion 31A of the upper swing arm 31 is inserted into an attachment member 66 to attach the stabilizer 30R to the vehicle body 210. The portion of the second connection shaft 41B above the portion inserted into the attachment member 66 includes an attachment

shaft 41C, to which the arm support portion 31A is attached, and a first male threaded portion 41D, which is located below the attachment shaft 41C and has a larger diameter than that of the attachment shaft 41C. The arm support portion 31A is located between a nut 69, which is attached to the attachment shaft 41C, and an upper end surface of the first male threaded portion 41D in the height direction ZC thereby connecting the upper swing arm 31 to the first arm shaft 41.

[0047] The attachment member 66 includes an insertion portion 66A, which has an insertion hole 66C (refer to Fig. 5) that receives the first connection shaft 41A is inserted, and a plate-shaped attachment portion 66B, which extends outward from the insertion portion 66A. The attachment member 66 is fixed to an upper fixing member 212R, which is fixed to the upper portion of the vehicle body 210, by bolts B inserted into two elongated holes 66D, which are formed in the attachment portion 66B and elongated in the vehicle width direction ZB. This allows for adjustment of the position of the attachment member 66 relative to the upper fixing member 212R in the vehicle width direction ZB.

[0048] As shown in Fig. 5, the second connection shaft 41B of the first arm shaft 41 is supported by a fourth rolling bearing 67 and a fifth rolling bearing 68 to be relative to the attachment member 66. The fourth rolling bearing 67 is a bearing integrally combining a thrust bearing 67A and a radial bearing 67B. The thrust bearing 67A is arranged on an upper surface of the insertion portion 66A, and the radial bearing 67B is arranged in an upper end portion of the insertion hole 66C of the insertion portion 66A. The fifth rolling bearing 68 is attached to a lower end portion of the insertion hole 66C of the insertion portion 66A. The thrust bearing 67A and the radial bearing 67B may be separately formed in the fourth rolling bearing 67. The thrust bearing 67A, the radial bearing 67B, and the fifth rolling bearing 68 may each be a ball bearing or a roller bearing.

[0049] As shown in Fig. 6, the upper fixing member 212R includes two holes 212A into which the bolts B are inserted. The upper fixing member 212R includes a plurality of first vertical serrations 212B extending in the vertical direction and formed on the portion of the upper fixing member 212R facing the attachment portion 66B.

[0050] The portion of the attachment portion 66B facing the upper fixing member 212R includes a plurality of second vertical serrations 66E extending in the vertical direction. The second vertical serrations 66E are meshed with the first vertical serrations 212B.

[0051] As shown in Figs. 4(b) and 7, the stabilizer 30R includes an arm adjustment mechanism 70 which is configured to adjust the distance between the upper swing arm 31 and the lower swing arm 32 (refer to Figs. 3(a) and 3(b)). As shown in Fig. 4(b), the arm adjustment mechanism 70 includes a first male threaded portion 41D which is provided on the second connection shaft 41B of the first arm shaft 41, a first nut 71 which is fastened to first male threaded portion 41D, and a lock nut 72 which

restricts rotation of the first nut 71 relative to the first male threaded portion 41D.

[0052] As shown in Fig. 7, the arm adjustment mechanism 70 includes a length adjustment unit 73 which adjusts an axial length of the first arm shaft 41. The length adjustment unit 73 includes a cylindrical connection member 46 which connects the first connection shaft 41A and the second connection shaft 41B of the first arm shaft 41 to each other. The second connection shaft 41B is connected to an upper end portion of the connection member 46 to restrict rotation of the second connection shaft 41B and axial movement of the second connection shaft 41B. In addition, the first connection shaft 41A is connected to a lower portion of the connection member 46 to restrict rotation of the first connection shaft 41A and axial movement of the first connection shaft 41A. Specifically, splines 41E are formed on the first connection shaft 41A, and splines (not shown) meshed with the splines 41E are formed on an inner circumferential portion of the connection member 46. In addition, the first connection shaft 51A of the first pinion shaft 51 and the third pinion shaft 53 are similar in construction to the first connection shaft 41A of the first arm shaft 41 and the third arm shaft 43. Accordingly, in Fig. 7, reference numerals of parts related to the pinion connection shaft 50 are included in parentheses.

[0053] Figs. 8(a) to 8(c) and 9 show a lower portion of the stabilizer 30R, particularly, the lower swing arm 32 and surroundings thereof.

[0054] As shown in Fig. 8(b), the lower swing arm 32 includes an arm support portion 32A which supports the second arm shaft 42 of the arm connection shaft 40 in a non-rotatable manner, a pinion support portion 32B which rotatably supports the second pinion shaft 52 of the pinion connection shaft 50, and a connection portion 32C which connects the arm support portion 32A and the pinion support portion 32B. The arm support portion 32A is tubular and has an insertion hole 32D (refer to Fig. 9), which receives the third arm shaft 43, and the pinion support portion 32B, which is tubular and has an insertion hole 32E (refer to Fig. 9) that receives the third pinion shaft 53. A dimension of the pinion support portion 32B in the height direction ZC is larger than a dimension of the arm support portion 32A in the height direction ZC. As shown in Fig. 8(a), the pinion support portion 32B includes an extension portion 32F extending in the front-rear direction ZA. The extension portion 32F includes a hole 32G into which a lock pin 23A (refer to Figs. 12(a) and 12(b)) of the lock cylinder 23R can be inserted.

[0055] As shown in Fig. 8(b), the portion of the second arm shaft 42 of the arm connection shaft 40 below the arm support portion 32A is inserted into the attachment member 66 to attach the stabilizer 30R to the vehicle body 210. For example, the attachment member 66 is fixed to a lower fixing member 213R, which is fixed to the lower side of the vehicle body 210, by bolts B inserted into two elongated holes 66D of the attachment portion 66B. The lower fixing member 213R has the same struc-

ture as the upper fixing member 212R. The portion of the lower fixing member 213R facing the attachment portion 66B includes a plurality of first vertical serrations 213A extending in the vertical direction. Second vertical serrations 66E of the attachment portion 66B are meshed with the first vertical serrations 213A.

[0056] As shown in Fig. 9, the second arm shaft 42 is supported by the first rolling bearing 82 and the second rolling bearing 83 to be rotatable relative to the attachment member 66. The first rolling bearing 82 is a bearing integrally combining a thrust bearing 82A and a radial bearing 82B. The thrust bearing 82A is arranged on the upper surface of the insertion portion 66A, and the radial bearing 82B is arranged on the upper end portion of the insertion hole 66C of the insertion portion 66A. The second rolling bearing 83 is attached to the lower end portion of the insertion hole 66C of the insertion portion 66A. The thrust bearing 82A and the radial bearing 82B may be formed separately in the first rolling bearing 82. The thrust bearing 82A, the radial bearing 82B, and the second rolling bearing 83 may each be a ball bearing or a roller bearing.

[0057] As shown in Fig. 8(b), the second pinion shaft 52 projects toward two opposite sides in the height direction ZC from the pinion support portion 32B. The lower pinion 34 is attached to the portion of the second pinion shaft 52 below the pinion support portion 32B in a non-rotatable manner. A support arm 80 is attached to the portion of the second pinion shaft 52 below the lower pinion 34. As shown in Fig. 8(a), the support arm 80 has substantially the same shape as the support arm 60. The rolling bodies 81 are attached to a distal end portion of the support arm 80 spaced apart in the front-rear direction ZA. The two rolling bodies 81 are rotatable about a rotation axis extending in the height direction ZC. As shown in Fig. 8(c), the two rolling bodies 81 are accommodated in a lower rail 222 which is provided on a lower end portion of the door 220R. The lower rail 222 extends in the front-rear direction ZA and is open downward. The two rolling bodies 81 are in contact with one of the two side walls of the lower rail 222 in the vehicle width direction ZB.

[0058] As shown in Fig. 9, the second pinion shaft 52 is supported by a third rolling bearing 84 and a fourth rolling bearing 85 so as to be rotatable about the lower swing arm 32. The third rolling bearing 84 is a bearing integrally combining the thrust bearing 84A and the radial bearing 84B. The thrust bearing 84A is arranged on an upper surface of the pinion support portion 32B, and the radial bearing 84B is arranged on the upper end portion of the insertion hole 32E of the pinion support portion 32B. The fourth rolling bearing 85 is attached to a lower end portion of the insertion hole 32E of the pinion support portion 32B. The support arm 80 is supported by a fifth rolling bearing 86 to be rotatable relative to the second pinion shaft 52. The thrust bearing 84A and the radial bearing 84B may be separately formed in the third rolling bearing 84. The thrust bearing 84A, the radial bearing 84B, the fourth rolling bearing 85, and the fifth rolling

bearing 86 may each be a ball bearing or a roller bearing.

[0059] As shown in Fig. 8(b), the stabilizer 30R includes a pinion adjustment mechanism 90 which is configured to adjust the distance between the upper pinion 33 and the lower pinion 34 (refer to Fig. 1(a)). The pinion adjustment mechanism 90 includes a second male threaded portion 52A which is provided on the portion of the second pinion shaft 52 above the pinion support portion 32B, a second nut 91 which is fastened to the second male threaded portion 52A, and a lock nut 92 which restricts rotation of the second nut 91 relative to the second male threaded portion 52A.

[0060] In addition, as shown in Fig. 7, the pinion adjustment mechanism 90 includes a length adjustment unit 93 which is configured to adjust the axial length of the first pinion shaft 51. In the same manner as the connection member 46, the length adjustment unit 93 includes a connection member 56. The length adjustment unit 93, which is similar in construction to the length adjustment unit 73 of the arm adjustment mechanism 70 includes splines 51E formed on the first connection shaft 51A of the first pinion shaft 51.

[0061] The adjustment of the stabilizer 30R with the arm adjustment mechanism 70 and the pinion adjustment mechanism 90 will now be described.

[0062] As shown in Fig. 4(b), the arm adjustment mechanism 70 adjusts the position of the upper swing arm 31 in the height direction ZC by adjusting a fastened amount of the first nut 71 to change the position of the first connection shaft 41A relative to the attachment member 66 in the height direction ZC. This results in the length adjustment unit 73 shown in Fig. 7 adjusting the axial length of the first arm shaft 41. Thus, the position of the second arm shaft 42 (refer to Figs. 3(a) and 3(b)) in the height direction ZC does not change. In this state, the length adjustment unit 93 shown in Fig. 7 adjusts the axial length of the first pinion shaft 51 in the pinion connection shaft 50. Thus, the position of the second pinion shaft 52 (refer to Figs. 3(a) and 3(b)) in the height direction ZC does not change. Accordingly, the arm adjustment mechanism 70 adjusts the distance between the upper swing arm 31 and the lower swing arm 32 in the height direction ZC.

[0063] As shown in Fig. 8(b), the pinion adjustment mechanism 90 adjusts the position of the lower pinion 34 in the height direction ZC by adjusting a fastened amount of the second nut 91 to change the position of the first connection shaft 51A relative to the attachment member 66 in the height direction ZC. This results in the length adjustment unit 93 shown in Fig. 7 adjusting the axial length of the first pinion shaft 51 and the length adjustment unit 73 adjusting the axial length of the first arm shaft 41. Thus, the positions of the upper pinion 33 and the upper swing arm 31 (refer to Figs. 3(a) and 3(b)) in the height direction ZC do not change. Accordingly, the pinion adjustment mechanism 90 adjusts the distance between the upper pinion 33 and the lower pinion 34 in the height direction ZC.

[0064] The operation of the plug door device 1 will now be described with reference to Figs. 1(a) to 3(b) and 11(a) to 12(b). The double-dashed lines in Figs. 10(a) and 10(b) show the doors 220R and 220L located at fully open positions.

[0065] First, the opening operation of the doors 220R and 220L will be described.

[0066] As shown in Figs. 11(a) and 11(b), when the doors 220R and 220L are located at the fully closed positions, the arms 21A (solid lines) of the retracting devices 21R and 21L retract the upper end portions of the pinion connection shafts 50 inward in the vehicle width direction ZB, and the arms 22A (solid lines) of the retracting devices 22R and 22L retract the lower end portions of the pinion connection shafts 50 inward in the vehicle width direction ZB. Accordingly, the distal end portions of the upper swing arm 31 and the lower swing arm 32 (refer to Figs. 10(a) and 10(b)) are prevented from rotating outward in the vehicle width direction ZB. In addition, as shown in Fig. 12(a), when the doors 220R and 220L are located at the fully closed positions, the lock pin 23A of each of the lock cylinder 23R and 23L is inserted into the hole 32G of the lower swing arm 32. This restricts rotation of the lower swing arm 32.

[0067] When a command signal for opening the doors 220R and 220L is received from a controller (not shown) of the vehicle 200, the arms 21A and 22A (two-dot chain lines) of the retracting devices 21R, 21L, 22R, and 22L are separated from the pinion connection shafts 50 as shown in Figs. 11(a) and 11(b). Further, as shown in Fig. 12(b), the lock pin 23A of each of the lock cylinders 23R and 23L is moved upward and out of the hole 32G of the lower swing arm 32. This allows the upper swing arm 31 and the lower swing arm 32 to rotate.

[0068] As shown in Figs. 2(a) and 3(a), the drive cylinder 12 is driven to move the doors 220R and 220L from the fully closed positions by moving the rods 11R and 11L toward opposite sides in the front-rear direction ZA. Accordingly, as shown in Fig. 1(a), the slide members 14R and 14L connected to the rods 11R and 11L move away from each other in the front-rear direction ZA. Therefore, the doors 220R and 220L move away from each other in the front-rear direction ZA with the door hangers 15R and 15L connected to the slide members 14R and 14L.

[0069] In this case, as shown in Figs. 2(a) and 2(b), the rolling bodies 15F move along the inclined portions 19A of the second rails 19R and 19L. As shown in Figs. 10(a) and 10(b), this synchronously rotates the upper swing arms 31 and the lower swing arms 32 of the stabilizers 30R and 30L. Further, the upper pinions 33 and the lower pinions 34 of the stabilizers 30R and 30L are synchronously rotated. The plug door device 1 is operated in this manner so that each of the doors 220R and 220L moves outward in the vehicle width direction ZB while moving in the front-rear direction ZA. In this case, as shown in Fig. 10(c), the two rolling bodies 230 on the lower end portion of each of the doors 220R and 220L

moves along the inclined portions 231A of the rails 231 (double-dashed lines) on the vehicle body 210.

[0070] Further, when the rolling body 15F moves along the linear portion 19B of each of the second rails 19R and 19L as shown in Figs. 2(a) and 2(b), the upper pinion 33 and the lower pinion 34 rotate synchronously but the upper swing arm 31 and the lower swing arm 32 do not rotate as shown in Figs. 10(a) and 10(b). Accordingly, the doors 220R and 220L move in only the front-rear direction ZA. In this case, as shown in Fig. 10(c), the two rolling bodies 230 move along the linear portions 231B of the rails 231.

[0071] The closing operation of the doors 220R and 220L will now be described.

[0072] As shown in Fig. 2(b), 10(a), and 10(b), when the doors 220R and 220L are located at the fully open positions and the plug door device 1 receives a command signal for closing the doors 220R and 220L from the controller, the drive cylinder 12 is controlled to move the rods 11R and 11L in directions opposite to the directions for opening the doors 220R and 220L. Accordingly, after the rolling body 15F moves on the linear portion 19B of each of the second rails 19R and 19L, the rolling body 15F moves on the inclined portion 19A. As the rolling body 15F moves on the linear portion 19B, the upper pinion 33 and the lower pinion 34 rotate synchronously. As the rolling body 15F moves on the inclined portion 19A, the upper pinion 33 and the lower pinion 34 rotate synchronously and the upper swing arm 31 and the lower swing arm 32 rotate synchronously. As shown in Fig. 10(c), after the two rolling bodies 230 move on the linear portions 231B of the rails 231, the two rolling bodies 230 move on the inclined portions 231A.

[0073] When the doors 220R and 220L are located at the fully closed positions as shown in Figs. 11(a) and 11(b), the retracting devices 21R, 21L, 22R, and 22L are driven such that the arms 21A and 22A retract the pinion connection shafts 50 inward in the vehicle width direction ZB. As shown in Fig. 12(a), the lock cylinders 23R and 23L are driven to downwardly move the lock pins 23A. As a result, each lock pin 23A is inserted into the hole 32G of the corresponding lower swing arm 32 thereby restricting rotation of the lower swing arm 32.

[0074] A method for attaching the plug door device 1 to the vehicle 200 will now be described with reference to Fig. 13. In the following description, the elements of the plug door device 1 and the vehicle 200 will be denoted by reference numerals indicating the elements of the plug door device 1 and the vehicle 200 shown in Fig. 1(a) to Fig. 9.

[0075] The attachment method of the plug door device 1 includes a device attachment process (step S1), a door temporary attachment process (step S2), a position adjustment process (step S3), and a door main attachment process (step S4).

[0076] In the device attachment process, the drive mechanism 10 and the stabilizers 30R and 30L are attached to the vehicle body 210 before the doors 220R

and 220L are attached. The second vertical serrations 66E of the upper-side attachment members 66 of the stabilizers 30R and 30L are meshed with the first vertical serrations 212B of the upper fixing members 212R and 212L, and the second vertical serrations 66E of the lower-side attachment members 66 are meshed with the first vertical serrations 213A of the lower fixing members 213R and 213L.

[0077] In the door temporary attachment process, the upper rails 221 of the doors 220R and 220L are placed on the second rolling bodies 62 of the support arms 60 of the stabilizers 30R and 30L. Accordingly, the doors 220R and 220L are supported by the stabilizers 30R and 30L, respectively. Prior to the door temporary attachment process, the upper rack 35, the lower rack 36, the upper rail 221, and the lower rail 222 are attached to the doors 220R and 220L.

[0078] In the position adjustment process, the positions of the upper swing arm 31, the lower swing arm 32, the upper pinion 33, the lower pinion 34, the support arm 60, and the support arm 80 in the height direction ZC are adjusted by the arm adjustment mechanism 70 and the pinion adjustment mechanism 90. Specifically, the position of the upper swing arm 31 in the height direction ZC relative to the upper-side attachment member 66 is changed with the arm adjustment mechanism 70 to adjust the positions of the doors 220R and 220L with respect to the vehicle body 210. In a case where the adjustment displaces the lower pinion 34 in the height direction ZC relative to the lower rack 36 or displaces the rolling body 81 of the support arm 80 in the height direction ZC relative to the lower rail 222, the pinion adjustment mechanism 90 changes the position of the lower swing arm 32 in the height direction ZC relative to the lower-side attachment member 66. Accordingly, the position of the lower pinion 34 is aligned with the lower rack 36 in the height direction ZC and the position of the rolling body 81 is aligned with the lower rail 222 in the height direction ZC.

[0079] Finally, in the door main attachment process, the doors 220R and 220L are attached by bolts (not shown) to the door hangers 15R and 15L, respectively. The longitudinal direction of the elongated holes 15E into which the bolts of each of the door hangers 15R and 15L are inserted is the height direction ZC. Thus, even when the positions of the doors 220R and 220L in the height direction ZC relative to the vehicle body 210 are changed, a bolt fixing hole (not shown) provided in each of the doors 220R and 220L is within a range of the elongated hole 15E.

[0080] The plug door device 1 of the present embodiment has the following advantages.

- (1) The arm connection shaft 40 inclines the third arm shaft 43 relative to the first arm shaft 41 and the second arm shaft 42 with the first universal joint 44 and the second universal joint 45 so that the axial directions of the first arm shaft 41 and the second arm shaft 42 extend in the vertical direction. By in-

clining the third pinion shaft 53 relative to the first pinion shaft 51 and the second pinion shaft 52 with the third universal joint 54 and the fourth universal joint 55, the pinion connection shaft 50 can synchronously connect the first pinion shaft 51 and the second pinion shaft 52. Accordingly, even in a case where the position of the upper swing arm 31 (upper pinion 33) in the vehicle width direction ZB is separated from the position of the lower swing arm 32 (lower pinion 34) in the vehicle width direction ZB, the rotation axes of the upper swing arm 31 and the lower swing arm 32 are not inclined relative to the vertical direction. Therefore, the weight of the doors 220R and 220L does not act as resistances against the rotations of the upper swing arm 31 and the lower swing arm 32. This allows the doors 220R and 220L to be smoothly moved.

[0081] In a case where the axial direction of the first pinion shaft 51 is inclined relative to the vertical direction, if the position of the upper pinion 33 in the vertical direction relative to the upper rack 35 differs from a preset position due to machining errors or assembly errors of the upper pinion 33 and the upper rack 35, the teeth of the upper pinion 33 are meshed with the teeth of the upper rack 35 at an inappropriate position in the direction (vehicle width direction ZB) in which the upper pinion 33 and the upper rack 35 face each other thereby causing the meshing force between the upper rack 35 and the upper pinion 33 to be excessively large or small. Thus, the upper pinion 33 will not rotate smoothly on the upper rack 35. In the same manner, in a case where the axial direction of the second pinion shaft 52 is inclined relative to the vertical direction, the lower pinion 34 will not rotate smoothly on the lower rack 36.

[0082] In this regard, the plug door device 1 of the present embodiment inclines the third pinion shaft 53 relative to the first pinion shaft 51 and the second pinion shaft 52 with the third universal joint 54 and the fourth universal joint 55. This adjusts the axial directions of the first pinion shaft 51 and the second pinion shaft 52 relative to the vertical direction. Accordingly, even when the position of the upper pinion 33 in the vertical direction relative to the upper rack 35 differs from the preset position due to machining errors or assembly errors of the upper pinion 33 and the upper rack 35, the position at which the teeth of the upper pinion 33 are meshed with the teeth of the upper rack 35 mesh with each other remain unchanged in the direction (vehicle width direction ZB) in which the upper pinion 33 and the upper rack 35 face each other. Accordingly, the upper pinion 33 and the upper rack 35 are meshed with each other with an appropriate force. Even when the position of the lower pinion 34 in the vertical direction with respect to the lower rack 36 differs from the preset position due to machining errors or assembly errors of the lower pinion 34 and the lower rack 36, the lower pinion 34 and the lower rack 36 are meshed with each other with an appropriate force. Ac-

cordingly, even in a case where the position of the upper pinion 33 in the vehicle width direction ZB is separated from the position of the lower pinion 34 in the vehicle width direction ZB, the upper pinion 33 rotates smoothly on the upper rack 35, and the lower pinion 34 rotates smoothly on the lower rack 36. Thus, the doors 220R and 220L are smoothly opened and closed.

[0083] If the arm connection shaft 40 were to be omitted from the plug door device 1, the pinion connection shaft 50 would need to transmit the rotation of one of the upper swing arm 31 and the lower swing arm 32 to the other one of the upper swing arm 31 and the lower swing arm 32. However, the third arm shaft 43 would be rotated relative to the first arm shaft 41 and the second arm shaft 42 by the universal joints 44 and 45. Thus, the rotation of one of the upper swing arm 31 and the lower swing arm 32 would not be appropriately transmitted to the other one of the upper swing arm 31 and the lower swing arm 32. Therefore, it would be difficult for the pinion connection shaft 50 to synchronize the rotations of the upper swing arm 31 and the lower swing arm 32.

[0084] In this regard, the plug door device 1 of the present embodiment synchronizes the rotations of the upper swing arm 31 and the lower swing arm 32 with the arm connection shaft 40, which is separate from the pinion connection shaft 50 that synchronizes the rotation of the upper pinion 33 and the lower pinion 34. This properly synchronizes the rotations of the upper swing arm 31 and the lower swing arm 32 and the rotations of the upper pinion 33 and the lower pinion 34.

(2) The arm adjustment mechanism 70 of the stabilizers 30R and 30L adjusts the distance between the upper swing arm 31 and the lower swing arm 32 and thereby adjusts the positions of the doors 220R and 220L relative to the vehicle body 210.

[0085] The positions of the doors 220R and 220L are changed relative to the vehicle body 210, and the positions of the lower rack 36 attached to the doors 220R and 220L are changed. Accordingly, the distance between the upper pinion 33 and the lower pinion 34 is changed with the pinion adjustment mechanism 90 so that the lower pinion 34 is located at the position at which the lower pinion 34 is meshed with the lower rack 36.

[0086] In a case where the distance between the upper rack 35 and the lower rack 36 differs between the doors 220R and 220L, the pinion adjustment mechanism 90 changes the distance between the upper pinion 33 and the lower pinion 34 to arrange the lower pinion 34 at the position where the lower pinion 34 is meshed with the lower rack 36.

(3) The distance between the upper swing arm 31 and the lower swing arm 32 is changed in accordance with the fastened amount of the first nut 71 of the arm adjustment mechanism 70. This adjusts the distance between the upper swing arm 31 and the

lower swing arm 32 in a stepless manner.

(4) The distance between the upper pinion 33 and the lower pinion 34 is changed in accordance with the fastened amount of the second nut 91 of the pinion adjustment mechanism 90. This adjusts the distance between the upper pinion 33 and the lower pinion 34 in a stepless manner.

(5) The connection member 46 of the arm connection shaft 40 and the first connection shaft 41A are spline-fitted to each other. This restricts relative rotation between the first connection shaft 41A and the second connection shaft 41B and allows the axial length of the first arm shaft 41 to be easily changed. Further, the pinion connection shaft 50 includes the connection member 56 and obtains the same advantages as the connection member 46.

(6) The second vertical serrations 66E of the attachment member 66 are meshed with the first vertical serrations 212B of each of the upper fixing members 212R and 212L. This restricts inclination of the attachment member 66 relative to each of the upper fixing members 212R and 212L. Accordingly, the arm connection shaft 40 inserted into the attachment member 66 is not inclined relative to each of the upper fixing members 212R and 212L. This further restricts inclination of the rotation axis of the upper swing arm 31 relative to the vertical direction. In addition, the second vertical serrations 66E of the attachment member 66 are meshed with the first vertical serrations 212B of each of the lower fixing members 213R and 213L. This further restricts inclination of the rotation axis of the lower swing arm 32 relative to the vertical direction.

(7) The upper pinion 33 and the upper rack 35 are arranged on the upper portion of each of the doors 220R and 220L, and the lower pinion 34 and the lower rack 36 are arranged on the lower portion of each of the doors 220R and 220L. Thus, the clothing near the waist of a passenger will not be caught in the rack and pinion and a child will not be able to reach the rack and pinion. In addition, the aesthetic appearance of each of the doors 220R and 220L can be improved.

45 Modification Examples

[0087] The description related with the above embodiment exemplifies, without any intention to limit, an applicable form of a plug door device according to the present invention. In addition to the embodiment described above, the plug door device according to the present invention is applicable to, for example, modified examples that are described below and combinations of at least two of the modified examples that do not contradict each other.

First Modification Example

[0088] The third arm shaft 43 in the arm connection shaft 40 may be formed by a plurality of shafts and a universal joint which connects the shafts in an integrally rotatable manner. In other words, the number of universal joints of the arm connection shaft 40 may be three or more.

Second Modification Example

[0089] The third pinion shaft 53 in the pinion connection shaft 50 may be formed by a plurality of shafts and a universal joint which connects the shafts in an integrally rotatable manner. In other words, the number of universal joints of the pinion connection shaft 50 may be three or more.

Third Modification Example

[0090] The arm adjustment mechanism 70 and the pinion adjustment mechanism 90 may be omitted from at least one of the stabilizers 30R and 30L.

Fourth Modification Example

[0091] The first vertical serrations 212B may be omitted from at least one of the upper fixing members 212R and 212L. The second vertical serrations 66E may be omitted from the attachment member 66 that is fixed to the upper fixing member from which the first vertical serrations 212B are omitted.

[0092] In addition, the first vertical serrations 213A may be omitted from at least one of the lower fixing members 213R and 213L. The second vertical serrations 66E may be omitted from the attachment member 66 that is fixed to the lower fixing member from which the first vertical serrations 213A are omitted.

Fifth Modification Example

[0093] The third arm shaft 43 may be omitted from the arm connection shaft 40. In this case, at least one of the first universal joint 44 and the second universal joint 45 extends toward the other of the first universal joint 44 and the second universal joint 45, and the first universal joint 44 and the second universal joint 45 are directly connected to each other. Accordingly, the first arm shaft 41 and the second arm shaft 42 are connected by only the first universal joint 44 and the second universal joint 45. In this case, at least one of the first universal joint 44 and the second universal joint 45 may have a shaft which replaces the third arm shaft 43. For example, in a case where the first universal joint 44 has a shaft extending toward the second universal joint 45 and the second universal joint 45 has no shaft, the shaft of the first universal joint 44 is connected to the second universal joint 45, and thus, the first universal joint 44 and the second universal

joint 45 are directly connected to each other. In addition, in a case where both the first universal joint 44 and the second universal joint 45 have the shafts, the first universal joint 44 and the second universal joint 45 are directly connected to each other by connecting the shaft of the first universal joint 44 and the shaft of the second universal joint 45 to each other.

Sixth Modification Example

[0094] The third pinion shaft 53 may be omitted from the pinion connection shaft 50. In this case, at least one of the third universal joint 54 and the fourth universal joint 55 extends toward the other of the third universal joint 54 and the fourth universal joint 55, and the third universal joint 54 and the fourth universal joint 55 are directly connected to each other. Accordingly, the first pinion shaft 51 and the second pinion shaft 52 are connected by only the third universal joint 54 and the fourth universal joint 55. In this case, at least one of the third universal joint 54 and the fourth universal joint 55 may have a shaft which replaces the third pinion shaft 53. For example, in a case where the third universal joint 54 has a shaft extending toward the fourth universal joint 55 and the fourth universal joint 55 has no shaft, the shaft of the third universal joint 54 is connected to the fourth universal joint 55, and thus, the third universal joint 54 and the fourth universal joint 55 are directly connected to each other. In addition, in a case where both the third universal joint 54 and the fourth universal joint 55 have the shafts, the third universal joint 54 and the fourth universal joint 55 are directly connected to each other by connecting the shaft of the third universal joint 54 and the shaft of the fourth universal joint 55 to each other.

Seventh Modification Example

[0095] At least one of the third universal joint 54 and the fourth universal joint 55 may be omitted from the pinion connection shaft 50. For example, in a case where both the third universal joint 54 and the fourth universal joint 55 are omitted from the pinion connection shaft 50, the third pinion shaft 53 is directly connected to each of the first pinion shaft 51 and the second pinion shaft 52.

[0096] In other words, the plug door device may be implemented as follows.

[0097] The plug door device includes a first swing arm and a second swing arm which are arranged spaced apart in a height direction of a door, a first pinion which is attached to a portion of the first swing arm separated from rotation axis of the first swing arm, a first rack which is attached to the door and meshes with the first pinion, a second pinion which is attached to a portion of the second swing arm separated from rotation axis of the second swing arm, a second rack which is attached to the door and meshes with the second pinion, and an arm connection shaft which includes a first arm shaft connected to the first swing arm and having an axis coinciding with the

rotation axis of the first swing arm, a second arm shaft connected to the second swing arm and having an axis coinciding with the rotation axis of the second swing arm, and a first universal joint and a second universal joint directly or indirectly connect the first arm shaft and the second arm shaft to each other. The arm connection shaft rotates integrally with the first swing arm and the second swing arm to synchronize rotation of the first swing arm and rotation of the second swing arm.

[0098] In addition, the plug door device may further include a third arm shaft which connects the first arm shaft and the second arm shaft to each other. The first universal joint may connect the first arm shaft and the third arm shaft, and the second universal joint may connect the second arm shaft and the third arm shaft.

Eighth modification example

[0099] At least one of the first universal joint 44 and the second universal joint 45 may be omitted from the arm connection shaft 40. For example, in a case where both the first universal joint 44 and the second universal joint 45 are omitted from the arm connection shaft 40, the third arm shaft 43 is directly connected to each of the first arm shaft 41 and the second arm shaft 42.

[0100] In other words, the plug door device may be implemented as follows.

[0101] The plug door device includes a first swing arm and a second swing arm which are arranged spaced apart in a height direction of a door, a first pinion which is attached to a portion of the first swing arm separated from rotation axis of the first swing arm, a first rack which is attached to the door and meshes with the first pinion, a second pinion which is attached to a portion of the second swing arm separated from rotation axis of the second swing arm, a second rack which is attached to the door and meshes with the second pinion, and a pinion connection shaft which includes a first pinion shaft connected to the first pinion and having an axis coinciding with the rotation axis of the first pinion, a second pinion shaft connected to the second pinion and having an axis coinciding with the rotation axis of the second pinion, and a third universal joint and a fourth universal joint directly or indirectly connect the first pinion shaft and the second pinion shaft to each other. The pinion connection shaft rotates integrally with the first pinion and the second pinion to synchronize rotation of the first pinion and rotation of the second pinion.

[0102] In addition, the plug door device may further include a third pinion shaft which connects the first pinion shaft and the second pinion shaft to each other, the third universal joint may connect the first pinion shaft and the third pinion shaft, and the fourth universal joint may connect the second pinion shaft and the third pinion shaft.

[0103] Problems of the plug door device of the eighth modification example are as follows.

[0104] With Japanese Laid-Open Patent Publication No. 6-262945, in a case where the door has a curved

shape and the position of the first pinion in the vehicle width direction is separated from the position of the second pinion in the vehicle width direction, the first pinion shaft and the second pinion shaft are provided in a state of being inclined relative to the vertical direction. Accordingly, when wear causes displacement of each part or lowers the door in the vertical direction, the position at which the teeth of the first pinion and the teeth of the first rack mesh with each other in the direction in which the first pinion and the first rack face each other may be changed, and the position at which the teeth of the second pinion and the teeth of the second rack mesh with each other in the direction in which the second pinion and the second rack face each other may be changed. Therefore, there is a concern that the opening and closing operations of the door are not smoothly performed.

[0105] Accordingly, the problem to be solved by the plug door device is to smoothly open and close the door.

[0106] It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the scope of the invention. For example, one or more of the components may be omitted from the components described in the embodiments (or one or more aspects thereof). Further, components in different embodiments may be appropriately combined.

[0107] The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

Claims

1. A plug door device (1) comprising:

- a first swing arm (31);
- a second swing arm (32) spaced apart from the first swing arm (31) in a height direction of a door (220R, 220L);
- a first pinion (33) attached to a portion of the first swing arm (31) separated from a rotation axis of the first swing arm (31);
- a first rack (35) attached to the door (220R, 220L) and meshed with the first pinion (33);
- a second pinion (34) attached to a portion of the second swing arm (32) separated from a rotation axis of the second swing arm (32);
- a second rack (36) attached to the door (220R, 220L) and meshed with the second pinion (34);
- an arm connection shaft (40) including a first arm shaft (41) connected to the first swing arm (31) and having an axis coinciding with the rotation axis of the first swing arm (31), a second arm shaft (42) connected to the second swing arm (32) and having an axis coinciding with the rotation axis of the second swing arm (32), and a

- third arm shaft (43) connecting the first arm shaft (41) and the second arm shaft (42), wherein the arm connection shaft (40) rotates integrally with the first swing arm (31) and the second swing arm (32) to synchronize rotation of the first swing arm (31) and rotation of the second swing arm (32); and
- a pinion connection shaft (50) including a first pinion shaft (51) connected to the first pinion (33) and having an axis coinciding with a rotation axis of the first pinion (33), a second pinion shaft (52) connected to the second pinion (34) and having an axis coinciding with a rotation axis of the second pinion (34), and a third pinion shaft (53) connecting the first pinion shaft (51) and the second pinion shaft (52), wherein the pinion connection shaft (50) rotates integrally with the first pinion (33) and the second pinion (34) to synchronize rotation of the first pinion (33) and rotation of the second pinion (34), wherein
- the arm connection shaft (40) includes a first universal joint (44), which connects the first arm shaft (41) and the third arm shaft (43), and a second universal joint (45), which connects the second arm shaft (42) and the third arm shaft (43), and
- the pinion connection shaft (50) includes a third universal joint (54), which connects the first pinion shaft (51) and the third pinion shaft (53), and a fourth universal joint (55), which connects the second pinion shaft (52) and the third pinion shaft (53).
2. The plug door device (1) according to claim 1, further comprising:
 - an arm adjustment mechanism (70) configured to adjust a distance between the first swing arm (31) and the second swing arm (32); and
 - a pinion adjustment mechanism (90) configured to adjust a distance between the first pinion (33) and the second pinion (34).
 3. The plug door device (1) according to claim 2, wherein:
 - the arm adjustment mechanism (70) includes a first male threaded portion (41D), which is provided on the first arm shaft (41), and a first nut (71), which is fastened to the first male threaded portion (41D); and
 - the first nut (71) is configured to change a position of the first swing arm (31) by moving in an axial direction of the first male threaded portion (41 D).
 4. The plug door device (1) according to claim 2 or 3, wherein:
 - the pinion adjustment mechanism (90) includes a second male threaded portion (52A), which is provided on the second pinion shaft (52), and a second nut (91), which is fastened to the second male threaded portion (52A); and
 - the second nut (91) is configured to change a position of the second pinion (34) by moving in an axial direction of the second male threaded portion (52A).
 5. The plug door device (1) according to claim 3 or 4, wherein at least one of the first arm shaft (41) and the first pinion shaft (51) includes:
 - a first connection shaft (41A, 51A) and a second connection shaft (41B, 51B) that are separately formed; and
 - a connection member (46, 56) connected to the first connection shaft (41A, 51A) to be non-rotatable to the first connection shaft (41A, 51A) and movable relative to the first connection shaft (41A, 51A) and connected to the second connection shaft (41B, 51B) to be non-rotatable to the second connection shaft (41B, 51B) and non-movable relative to the second connection shaft (41B, 51B).
 6. The plug door device (1) according to any one of claims 1 to 5, further comprising:
 - an attachment member (66) configured to attach the first arm shaft (41) to a vehicle body (210), wherein
 - the attachment member (66) is configured to be attached to a fixing member (212R, 212L, 213R, 213L) provided on the vehicle body (210) and including a first vertical serration (212B, 213A) extending in a vertical direction, and
 - the attachment member (66) includes a second vertical serration (66E) configured to be meshed with the first vertical serration (212B, 213A).
 7. The plug door device (1) according to any one of claims 1 to 6, wherein
 - the first pinion (33) and the first rack (35) are arranged on an upper portion of the door (220R, 220L), and
 - the second pinion (34) and the second rack (36) are arranged on a lower portion of the door (220R, 220L).

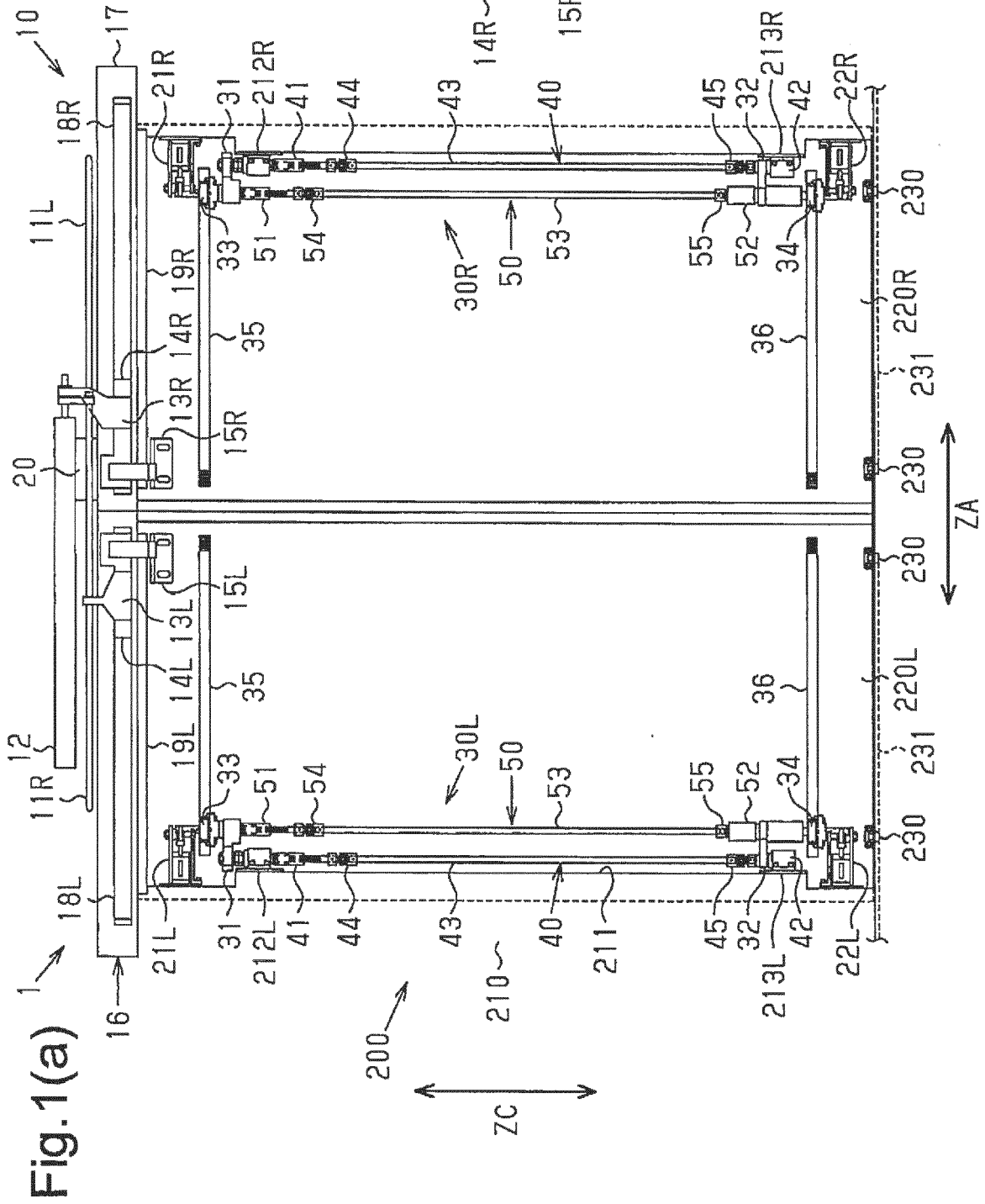


Fig. 2(a)

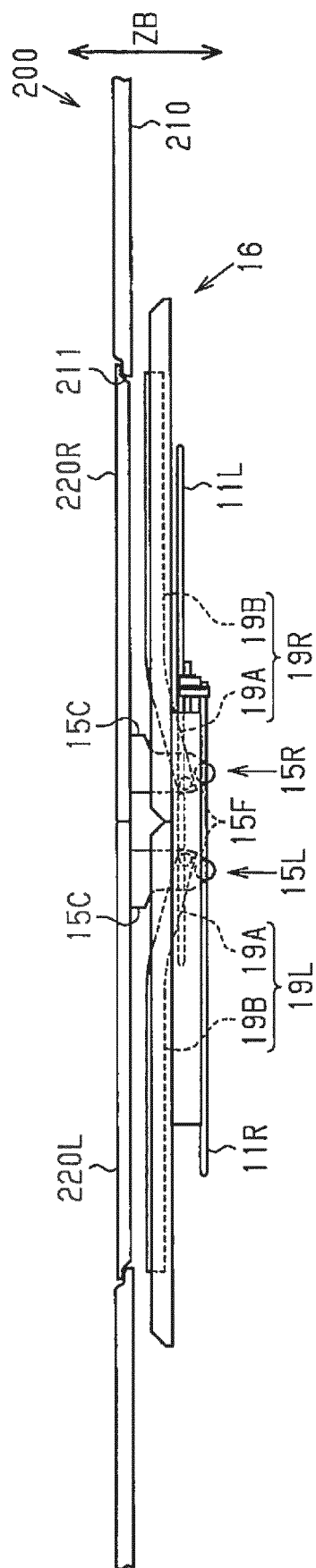


Fig. 2(b)

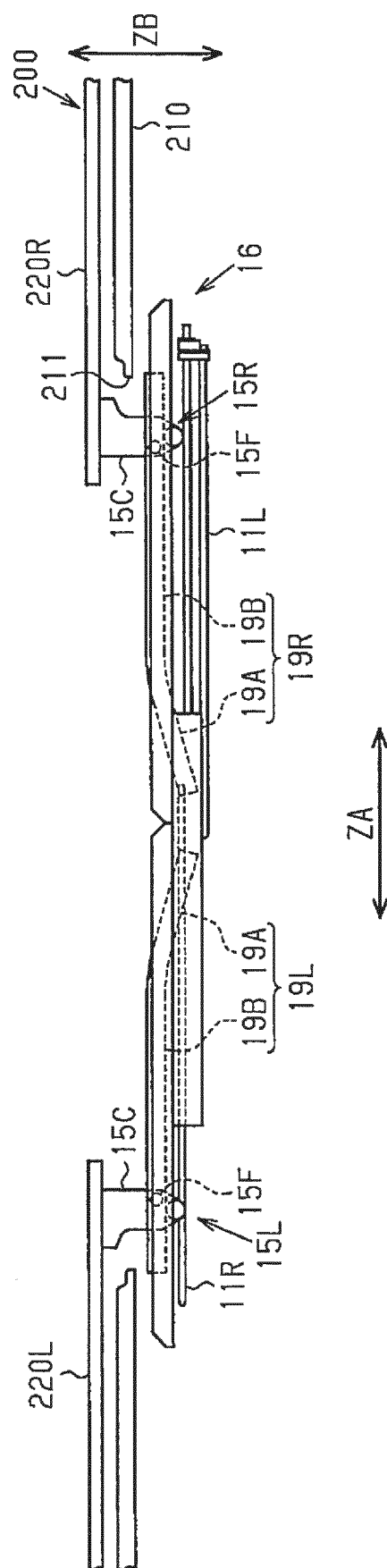


Fig.3(a)

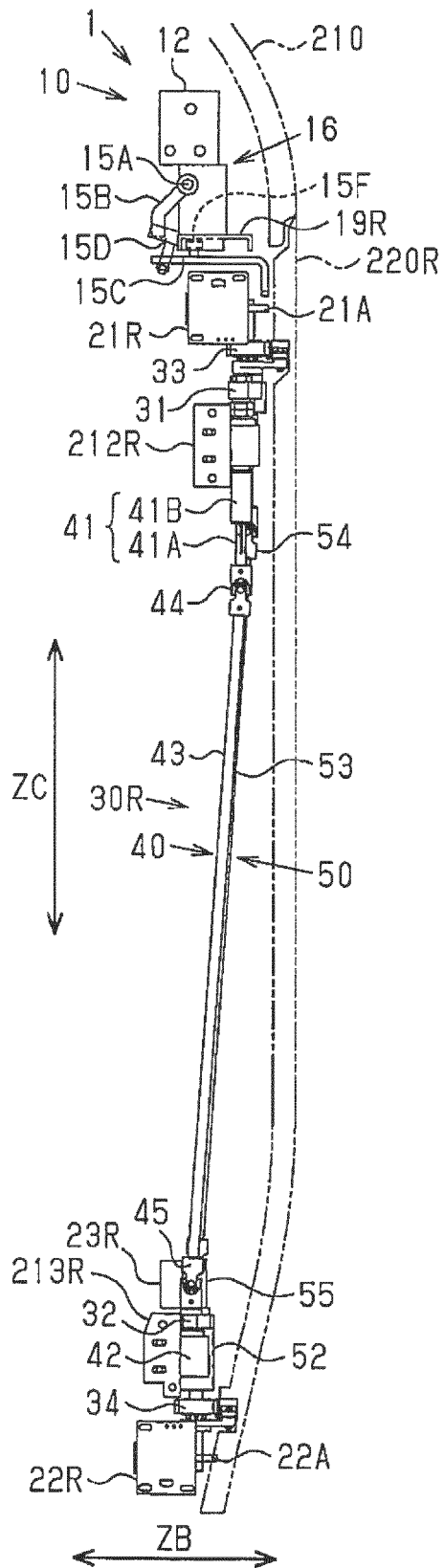
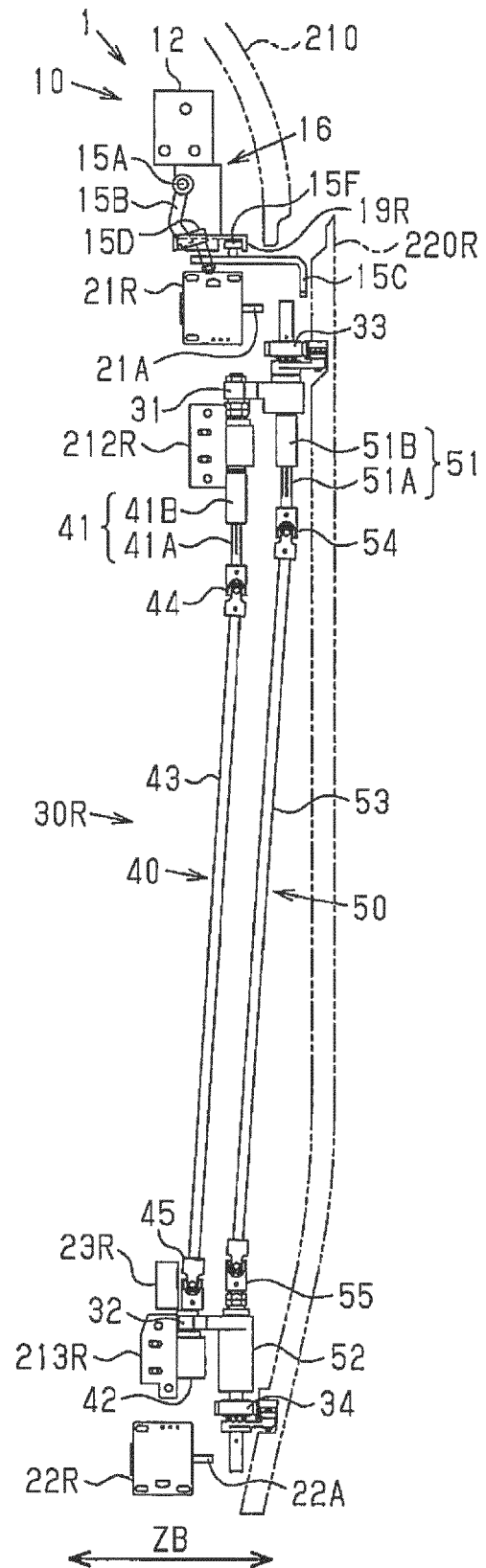


Fig.3(b)



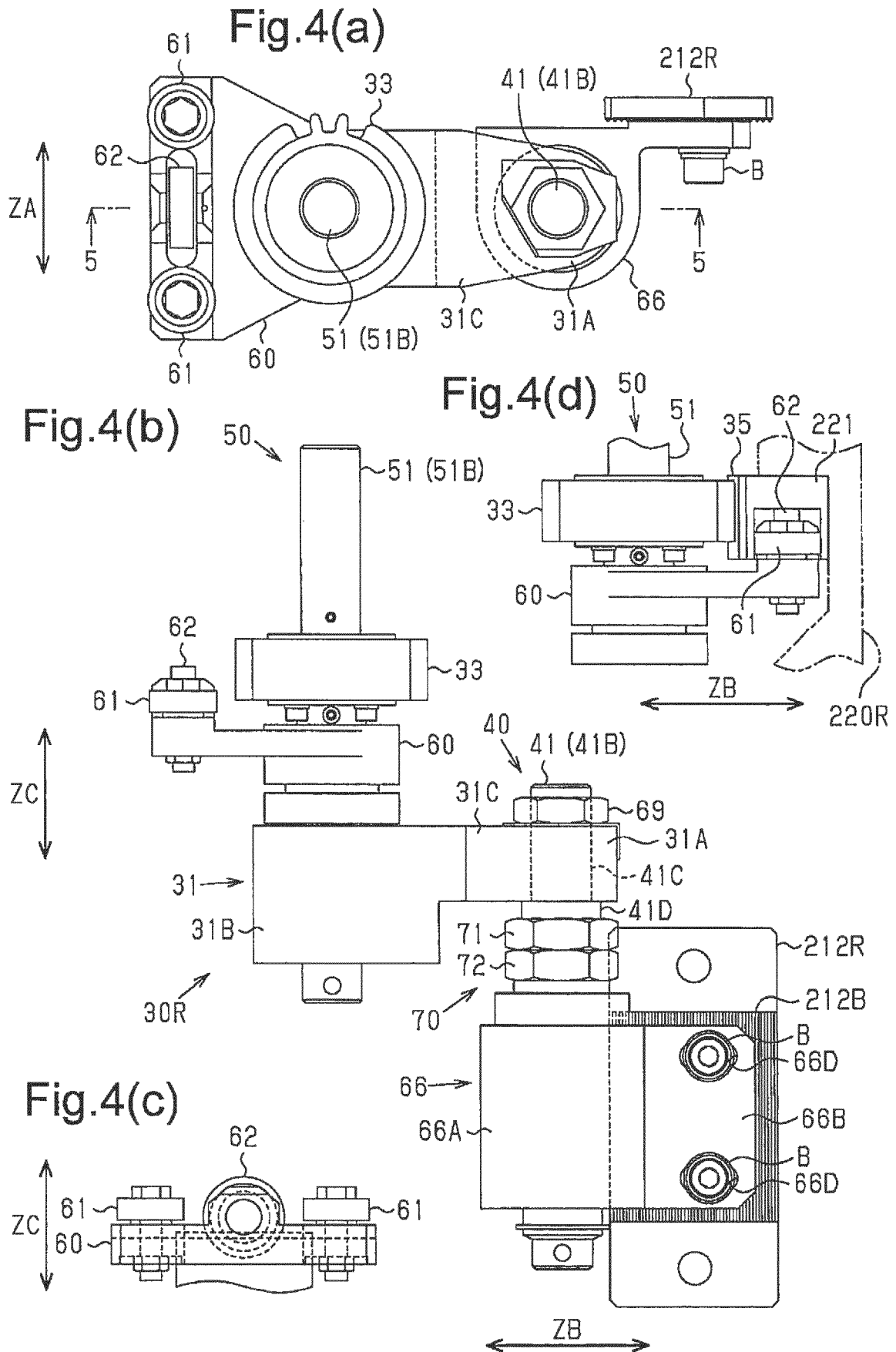


Fig.5

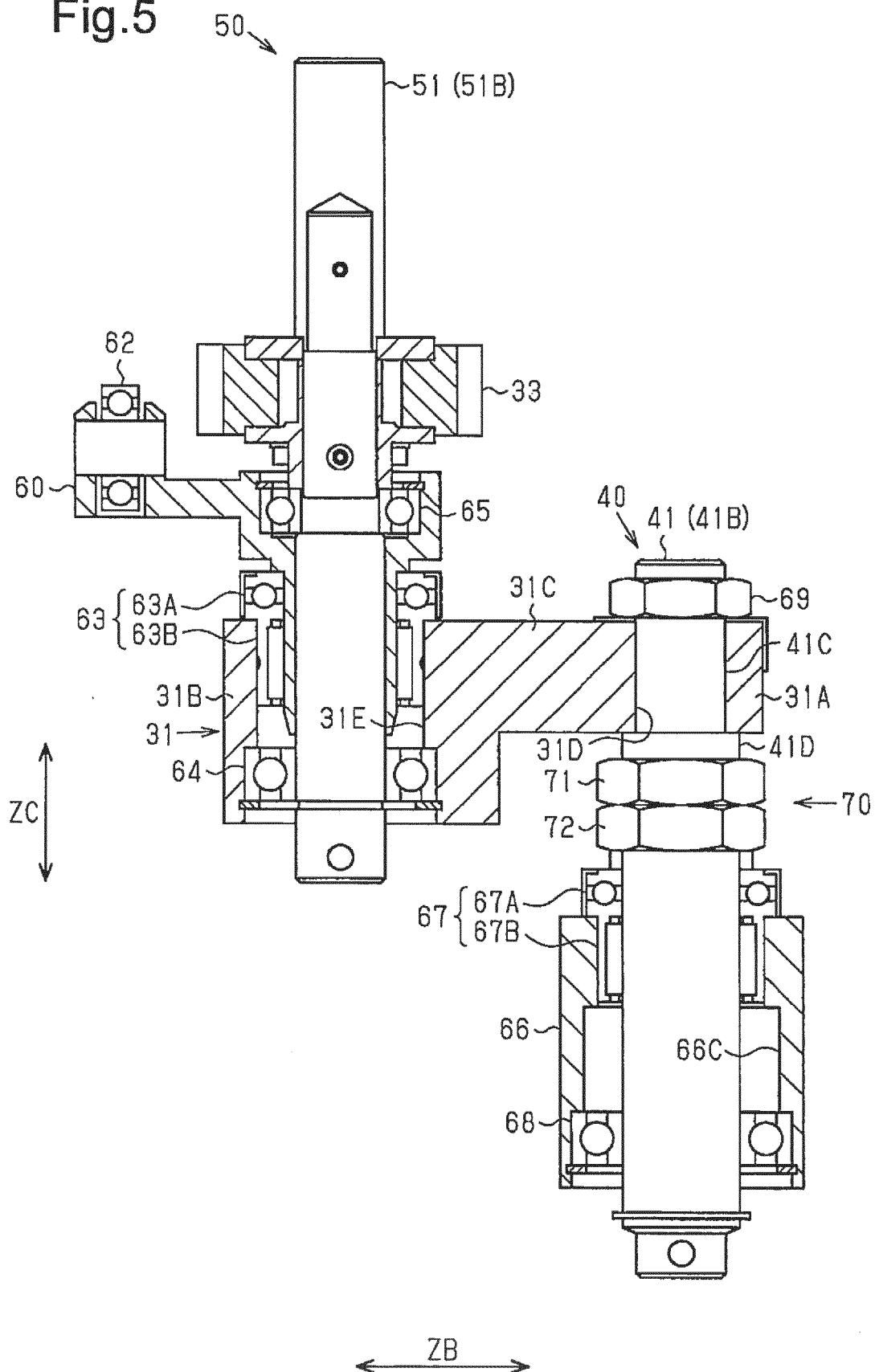


Fig.6

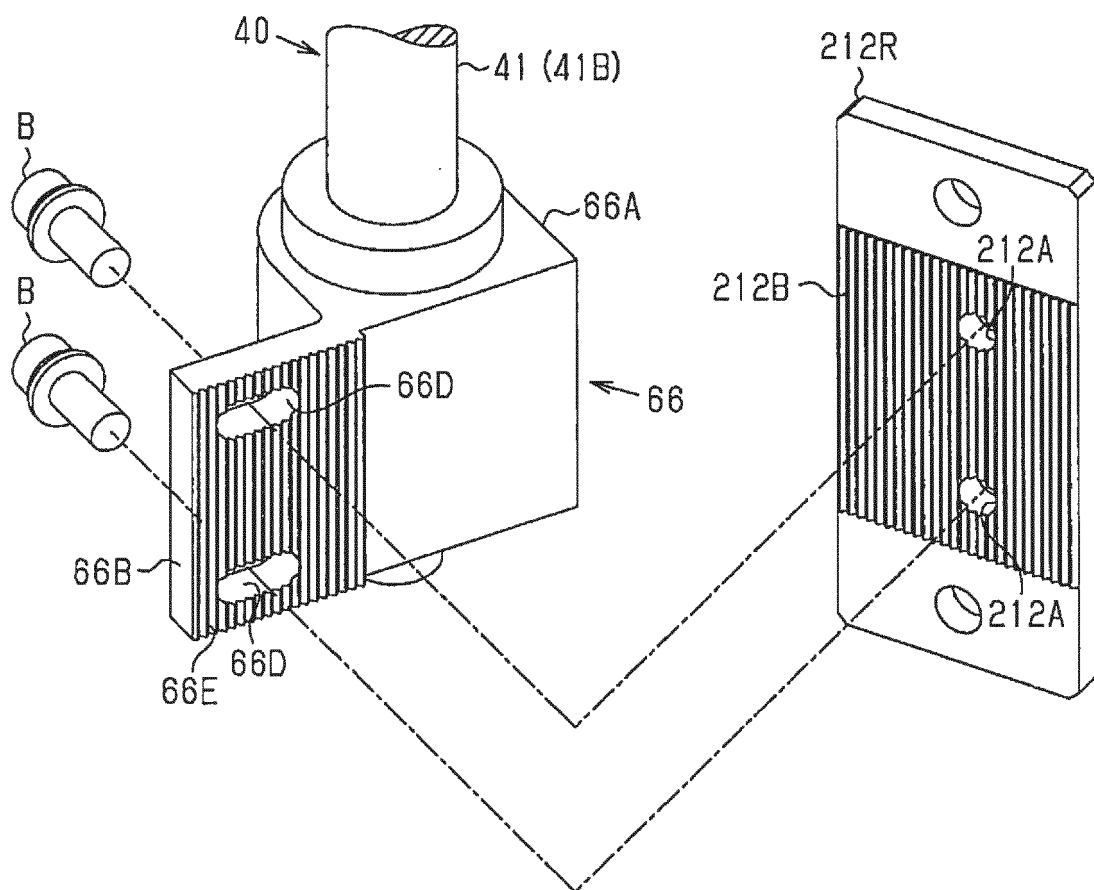
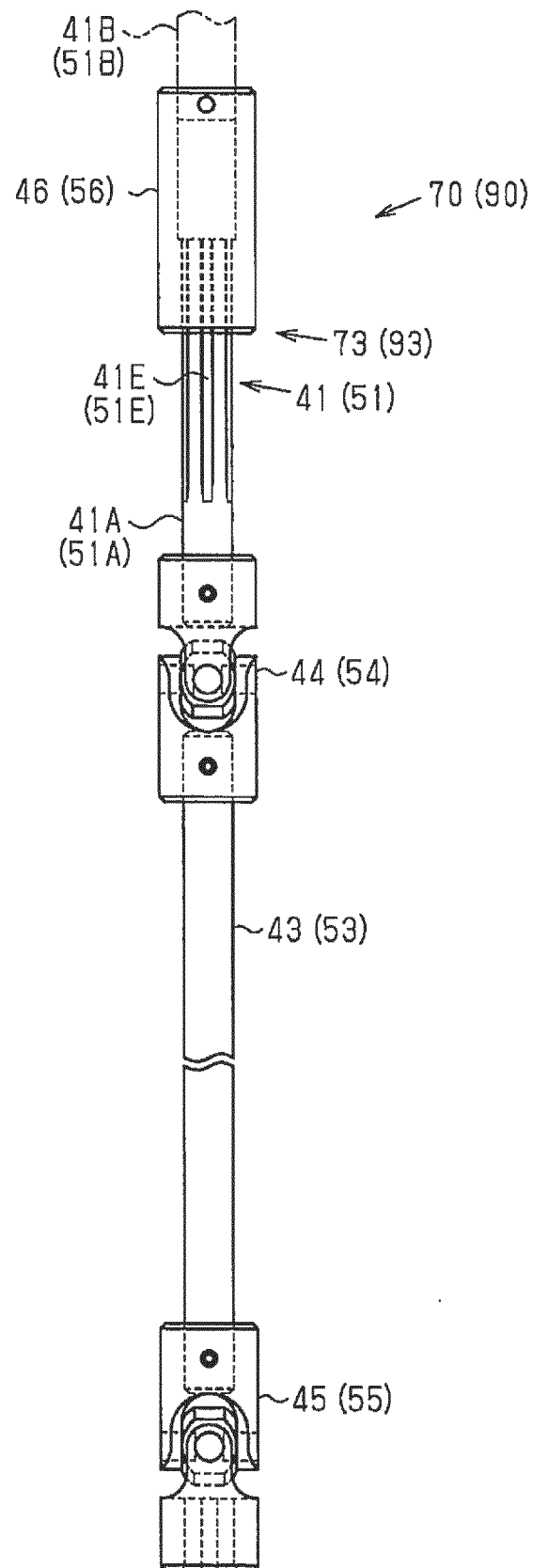


Fig.7



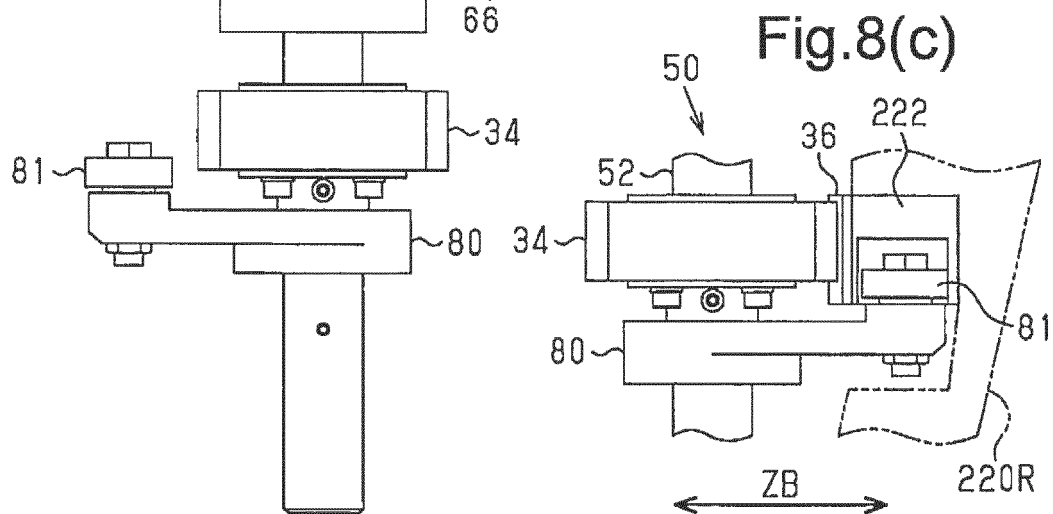
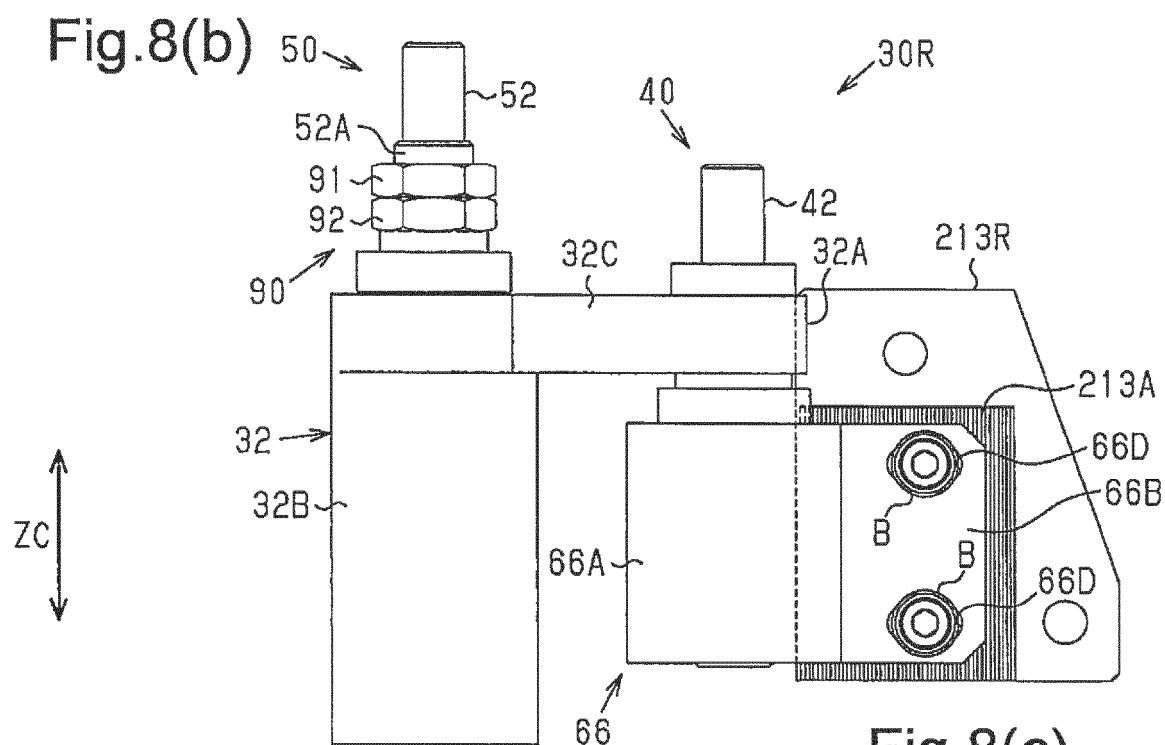
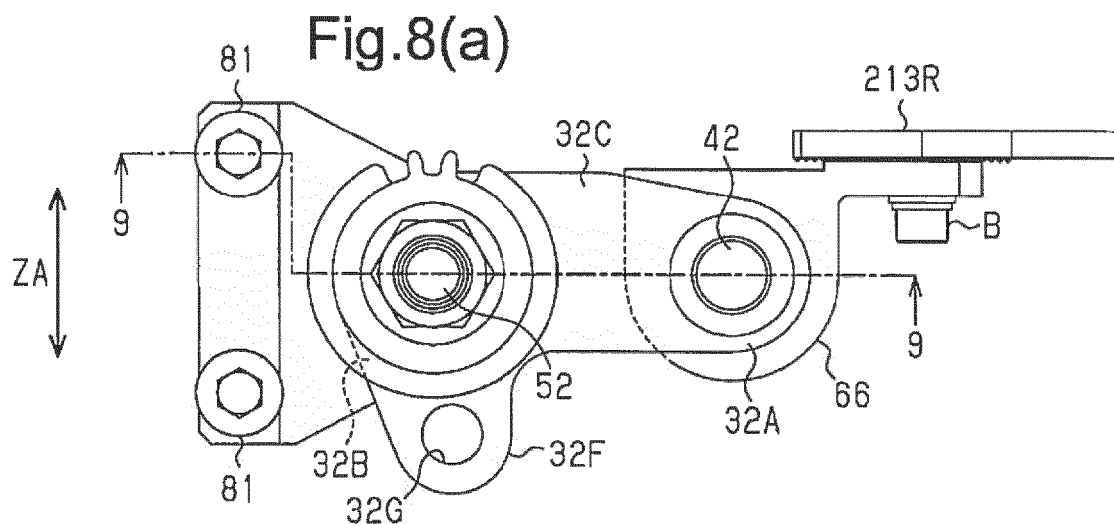


Fig.9

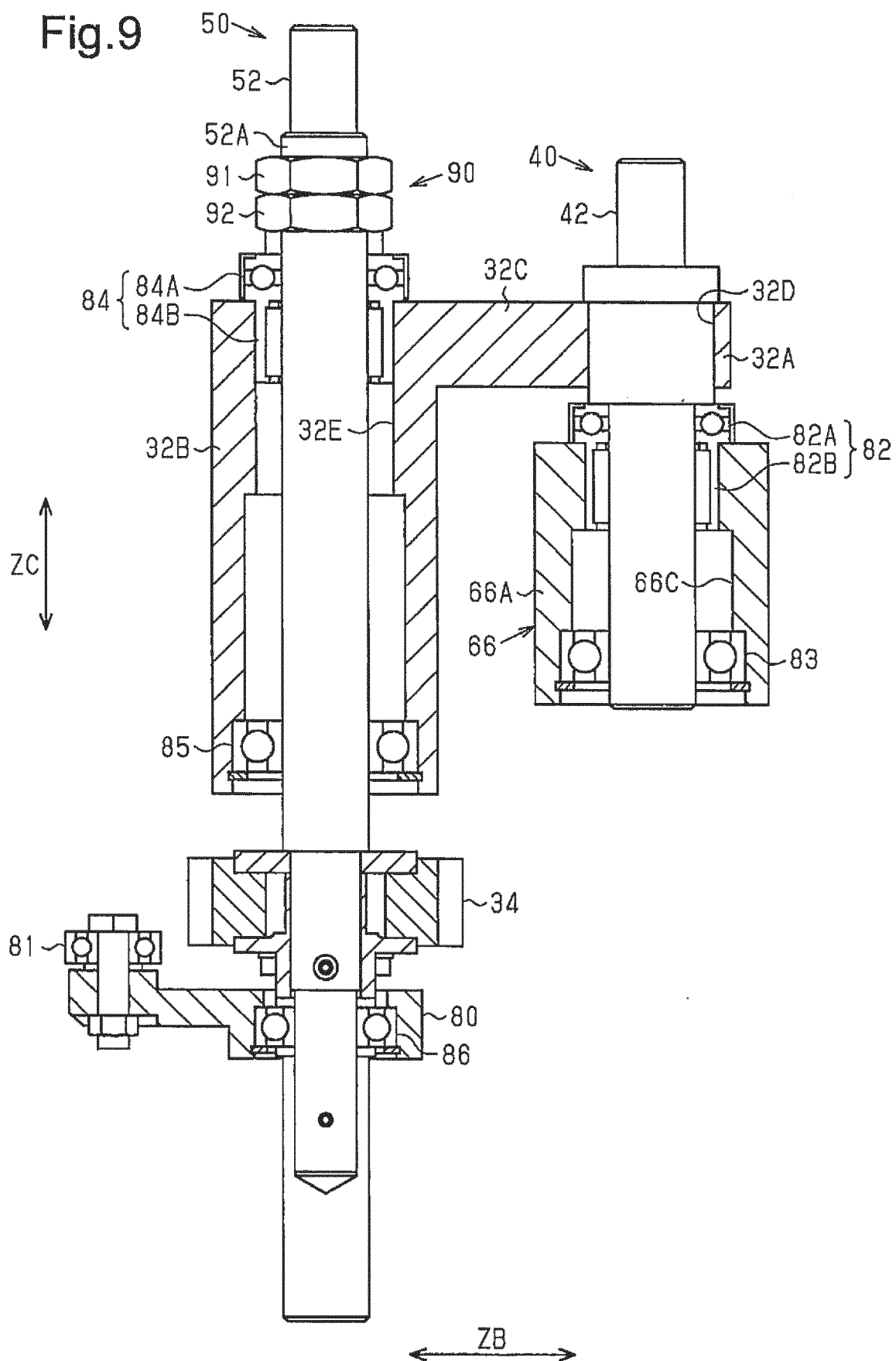


Fig. 10(a)

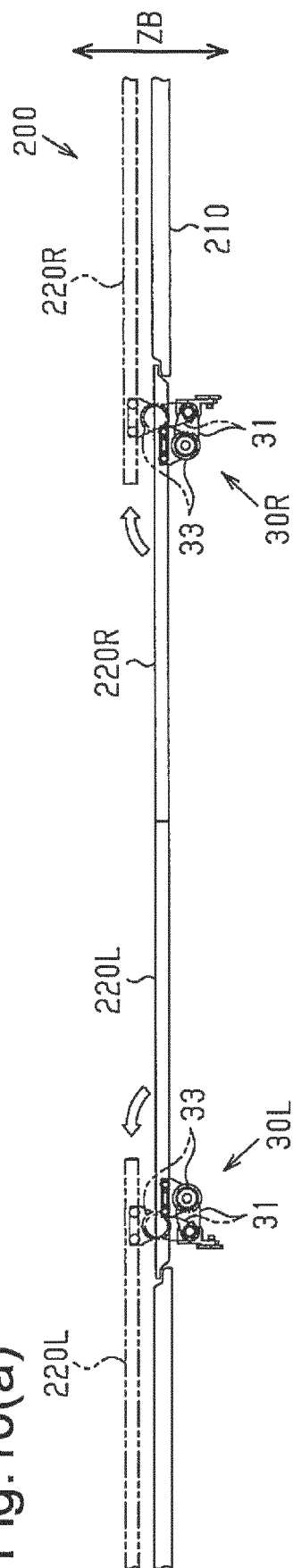


Fig. 10(b)

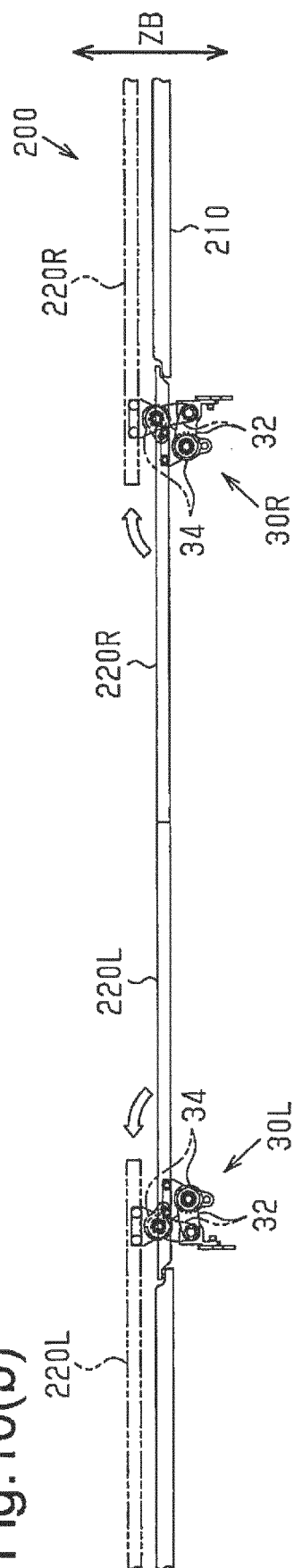


Fig. 10(c)

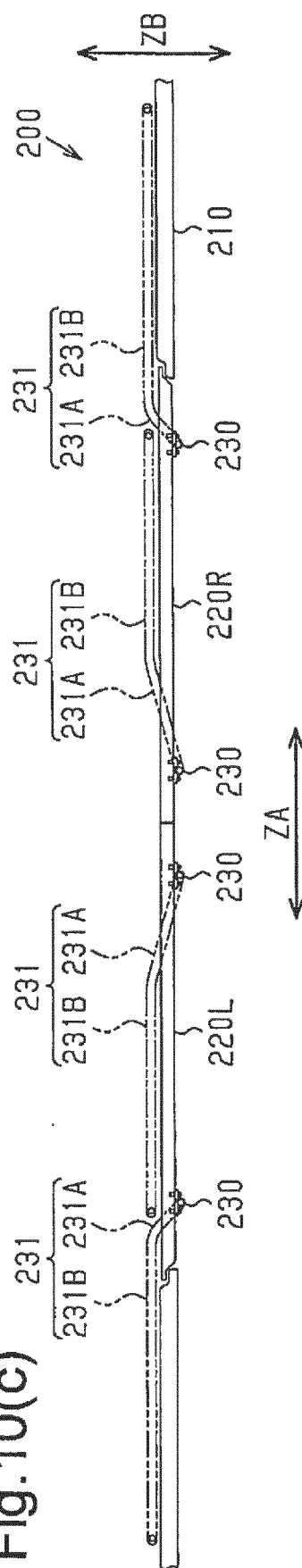


Fig.11(a)

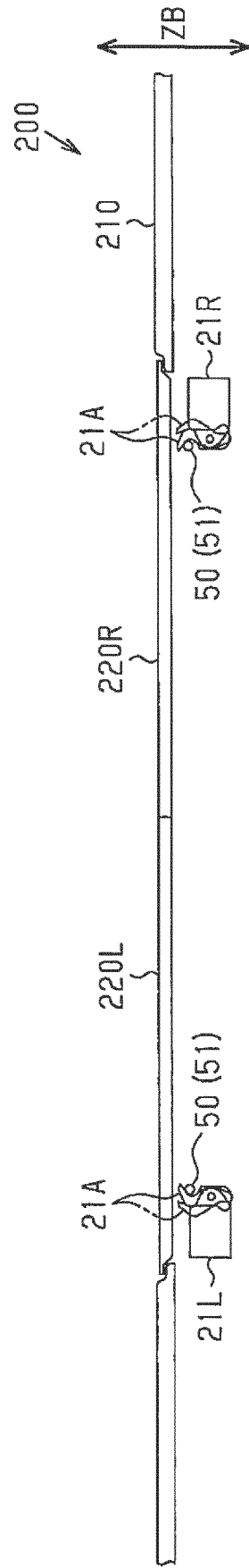


Fig.11(b)

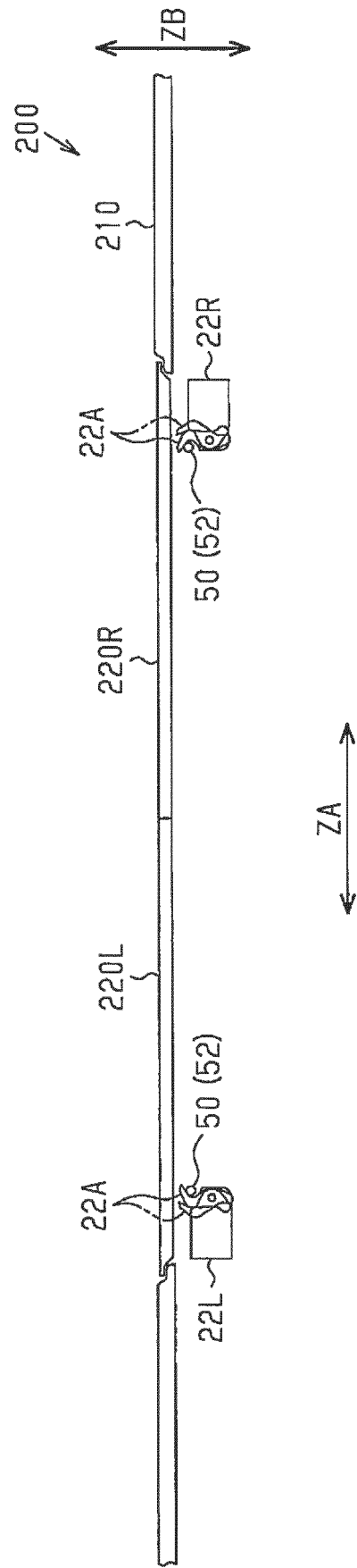


Fig.12(a)

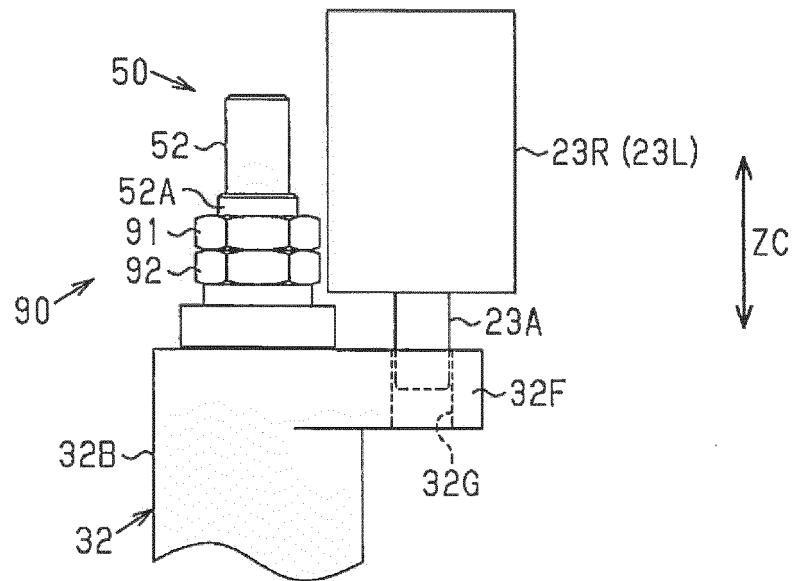


Fig.12(b)

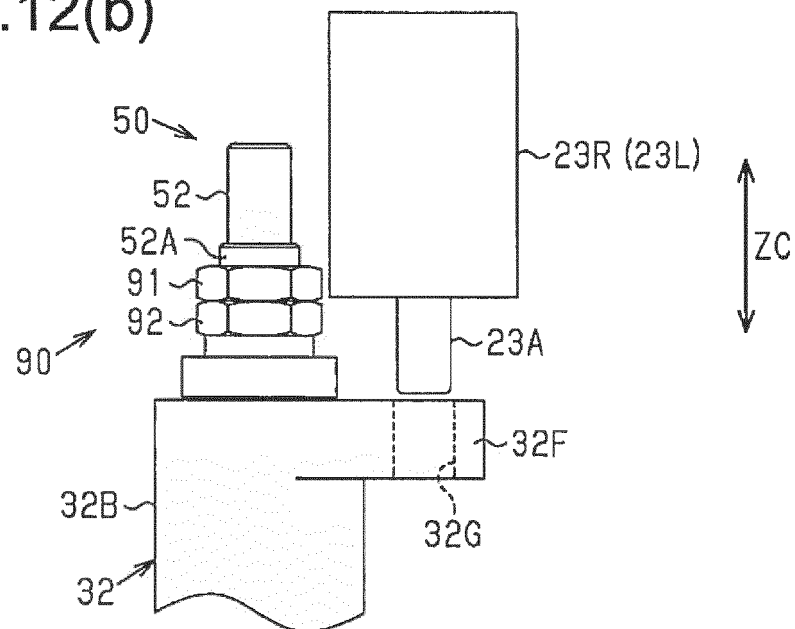


Fig.13

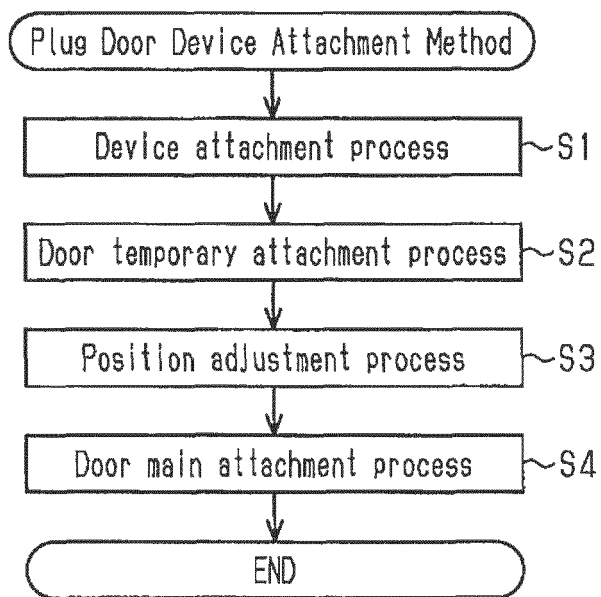


Fig.14

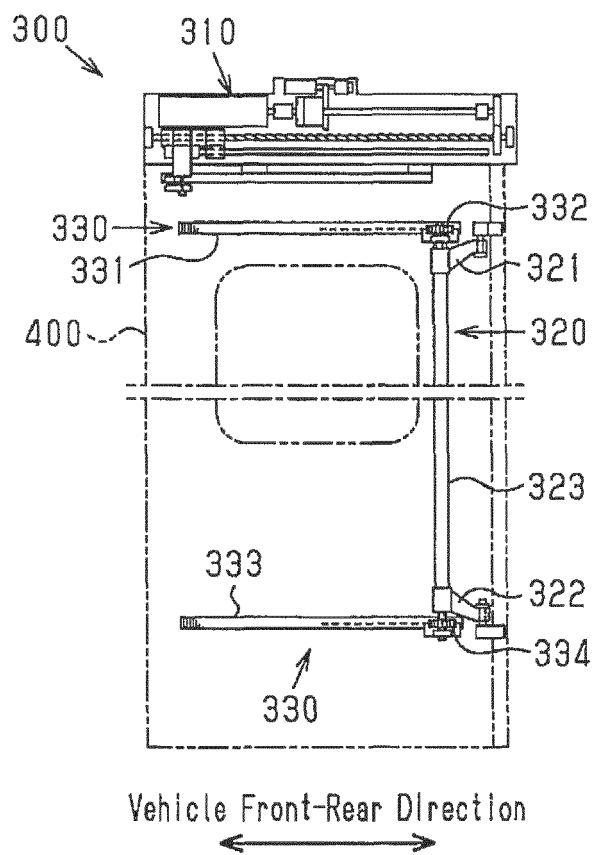
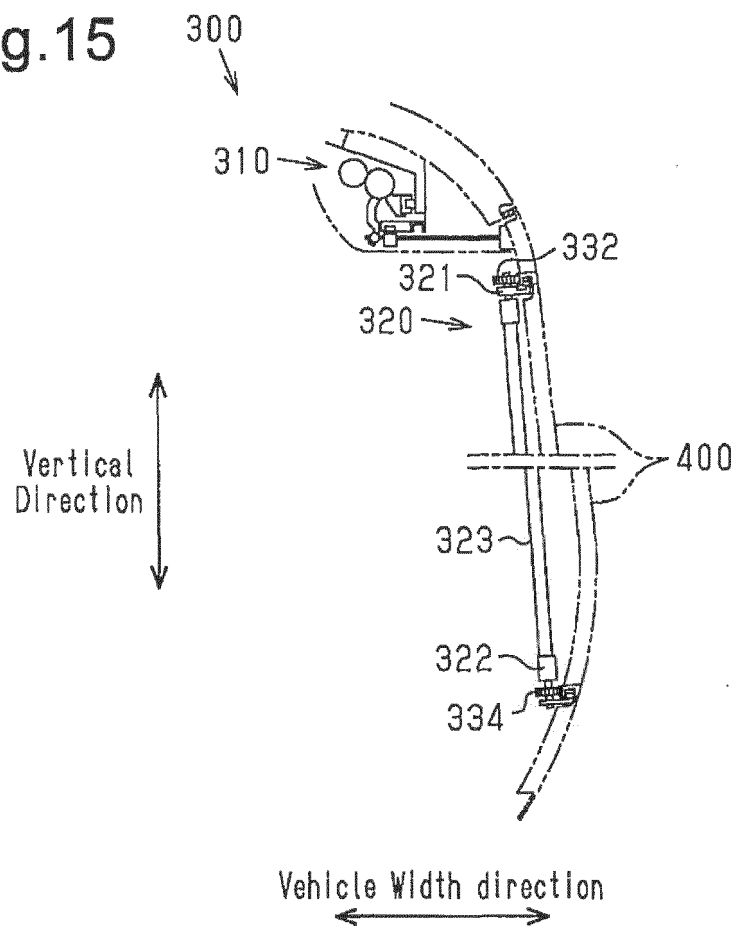


Fig.15





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Application Number
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A	* page 11, paragraphs 2,3 * * figures 1,2 *	2-5	
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A	* paragraphs [0011], [0014], [0015] * * claim 4 * * figures 1,3,7 *	2-5	
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Place of search The Hague		Date of completion of the search 17 June 2019	Examiner Wagner, Andrea
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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