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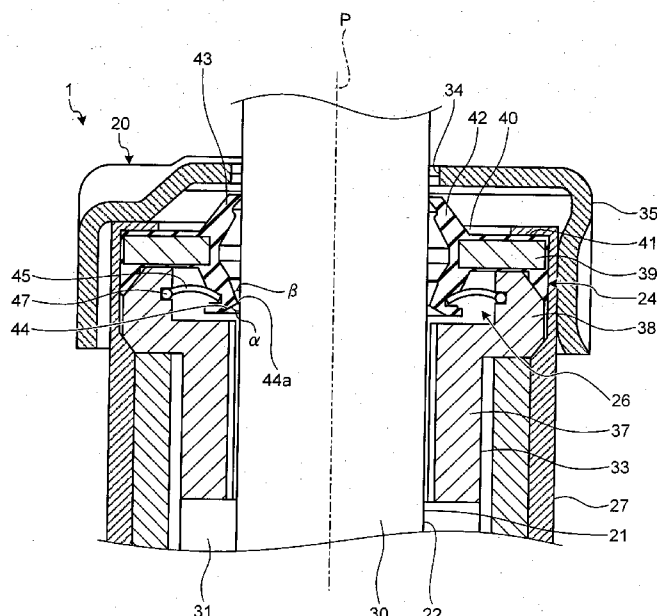
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[Continued on next page]

(54) Title: SUSPENSION DEVICE

FIG.2



(57) Abstract: To provide a suspension device capable of improving riding comfort more while reducing its size when a vehicle travels. A suspension device 1 includes a cylinder 21 having hydraulic oil sealed therein, a piston 22, an oil seal 24, and a lip portion angle changer 26. The oil seal 24 includes an oil lip 44 in contact with a piston rod 30. The lip portion angle changer 26 can change the angle of the lower surface 44b of the oil lip 44 to the axial center P of the piston rod 30 and the angle of the upper surface 44c of the oil lip 44 to the axial center P of the piston rod 30.



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DESCRIPTION

SUSPENSION DEVICE

TECHNICAL FIELD

The present invention relates to a suspension device.

BACKGROUND ART

Vehicles are mounted with a suspension device for ensuring riding comfort when they travel and ensuring the follow-up performance of a wheel to a road surface. The suspension device has an elastic member such as a spring between a vehicle body and the wheel. The suspension device changes the relative positional relation between the vehicle body and the wheel according to the state of a road surface on which a vehicle travels and thereby can absorb a shock from the road surface to the vehicle body by elastically deforming the elastic member. The suspension device is further provided with a damping mechanism for damping a periodic vibration caused by the elastic deformation of the elastic member. In recent years, to improve the riding comfort more when a vehicle travels, a technology has been developed to change the friction of a damping mechanism according to the traveling state of the vehicle when the periodic vibration of the elastic member is damped.

CITATION LIST

PATENT LITERATURE

Patent Literature 1: Japanese Patent Application Laid-open No. 2009-243584

DISCLOSURE OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

The suspension device described above is required to improve riding comfort more while reducing its size when a vehicle travels.

An object of the present invention, which was made in view of the circumstances, is to provide a suspension device capable of improving riding comfort more while reducing its size when a vehicle travels.

SOLUTIONS TO THE PROBLEMS

A suspension device according to the present invention includes an oil seal that configured to seal working fluid in a cylinder and include a lip portion in contact with a piston rod of a piston; and a lip portion angle changer capable of changing an angle of a surface of the lip portion to an axis center of the piston rod.

Further, it is preferable that the lip portion angle changer changes the angle of a surface of the lip portion to the axis center of the piston rod based on a moving direction of a sprung member.

Further, it is preferable that when the sprung member moves upward, the lip portion angle changer increases the angle of the upper surface of the lip portion to the piston rod and decreases the angle of the lower surface of the lip portion to the piston rod, and when the sprung member moves downward, the lip portion angle changer decreases the angle of the upper surface of the surface of the lip portion to the piston rod and increases the angle of the lower surface of the surface of the lip portion to the piston rod.

Further, it is preferable that the lip portion angle changer includes a lip upper portion angle changer that changes the angle of the upper surface of the surface of the lip portion to the piston rod, and a lip lower portion

angle changer that changes the angle of the lower surface of the surface of the lip portion to the piston rod, and wherein, the lip portion angle changer changes the angle of the upper surface of the lip portion and the angle of the lower surface of the lip portion according to the moving direction of the piston rod to the cylinder.

Further, it is preferable that when the piston rod moves upward with respect to the cylinder, the lip portion angle changer causes the lip lower portion angle changer to decrease the angle of the lower surface to the piston rod, and when the piston rod moves downward to the cylinder, the lip portion angle changer causes the lip upper portion angle changer to decrease the angle of the upper surface to the piston rod.

EFFECTS OF THE INVENTION

The suspension device according to the present invention provided with the lip portion angle changer for changing the angle of the lip portion can achieve the effect that riding comfort can be more improved while reducing its size when a vehicle travels.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a longitudinal sectional view illustrating a schematic configuration of a suspension device according to a first embodiment.

FIG. 2 is a longitudinal sectional view illustrating a main portion of a damping mechanism of the suspension device according to the first embodiment.

FIG. 3 is a longitudinal sectional view illustrating an oil seal of the damping mechanism of the suspension device according to the first embodiment.

FIG. 4 is a longitudinal sectional view illustrating

an IV portion in FIG. 3 in enlargement.

FIG. 5 is a plan view illustrating a lip portion angle changer of the damping mechanism of the suspension device according to the first embodiment.

FIG. 6 is a sectional view along a line VI-VI in FIG. 5.

FIG. 7 is a longitudinal sectional view illustrating the state that the lip portion angle changer of the damping mechanism of the suspension device according to the first embodiment directs an oil lip downward.

FIG. 8 is a longitudinal sectional view illustrating an VIII portion in FIG. 7 in enlargement.

FIG. 9 is a longitudinal sectional view illustrating the state that the lip portion angle changer of the damping mechanism of the suspension device according to the first embodiment directs the oil lip upward.

FIG. 10 is a longitudinal sectional view illustrating an X portion in FIG. 9 in enlargement.

FIG. 11 illustrates an example of a flowchart for causing an ECU of the suspension device according to the first embodiment of the present invention to change the angle of an oil lip of the oil seal.

FIG. 12 is a view explaining the operation when a wheel of the suspension device according to the first embodiment of the present invention gets over a convex portion of a road surface.

FIG. 13 is a view explaining the angle of the oil lip of the oil seal when the wheel illustrated in FIG. 12 gets over the convex portion of the road surface.

FIG. 14 is a longitudinal sectional view illustrating a configuration of a main portion of an oil seal of a suspension device according to a second embodiment.

FIG. 15 is a longitudinal sectional view illustrating

a XIV portion in FIG. 14 in enlargement.

FIG. 16 is a longitudinal sectional view illustrating the state that the angle of an oil lip of the oil seal of the suspension device according to the second embodiment is decreased.

FIG. 17 is a view illustrating the surface pressure of the oil seal of FIG. 16 in the axis center direction of the oil lip.

FIG. 18 is a longitudinal sectional view illustrating the state that the angle of the oil lip of the oil seal of the suspension device according to the second embodiment is decreased.

FIG. 19 is a view illustrating the surface pressure of the oil seal of FIG. 18 in the axis center direction of the oil lip.

FIG. 20 illustrates an example of a flowchart for causing an ECU of the suspension device according to the second embodiment of the present invention to change the angle of the oil lip of the oil seal.

DESCRIPTION OF EMBODIMENTS

Embodiments according to the present invention will be explained below in detail based on the drawings. The present invention is not limited by the embodiments. The components in the embodiments include the components that can be replaced by a person skilled in the art and easy or substantially the same components. Namely, the present invention can be embodied by being variously modified by appropriately combining the components shown in the embodiments in the range that does not depart from the gist of the present invention.

First Embodiment

A suspension device according to a first embodiment of

the present invention will be explained based on FIG. 1 to FIG. 13. FIG. 1 is a longitudinal sectional view illustrating a schematic configuration of a suspension device according to the first embodiment, FIG. 2 is a longitudinal sectional view illustrating a main portion of a damping mechanism of the suspension device according to the first embodiment, FIG. 3 is a longitudinal sectional view illustrating an oil seal of the damping mechanism of the suspension device according to the first embodiment, FIG. 4 is a longitudinal sectional view illustrating a IV portion in FIG. 3 in enlargement, FIG. 5 is a plan view illustrating a lip portion angle changer of the damping mechanism of the suspension device according to the first embodiment, FIG. 6 is a sectional view along a line VI-VI in FIG. 5, FIG. 7 is a longitudinal sectional view illustrating the state that the lip portion angle changer of the damping mechanism of the suspension device according to the first embodiment directs an oil lip downward, FIG. 8 is a longitudinal sectional view illustrating an VIII portion in FIG. 7 in enlargement, FIG. 9 is a longitudinal sectional view illustrating the state that the lip portion angle changer of the damping mechanism of the suspension device according to the first embodiment directs the oil lip upward, and FIG. 10 is a longitudinal sectional view illustrating a X portion in FIG. 9 in enlargement.

A suspension device 1 according to the first embodiment illustrated in FIG. 1 is disposed to each of wheels of a vehicle in one-on-one relation to support a wheel by a vehicle body of the vehicle. The suspension device 1 is disposed between a sprung member 5 of the vehicle (illustrated in FIG. 12) and an unsprung member 6 of the vehicle (illustrated in FIG. 12) and connects the sprung member 5 to the unsprung member 6. The sprung

member 5 is a member supported by the suspension device 1 and includes the vehicle body. The unsprung member 6 is a member disposed nearer to the wheel than the suspension device 1 and includes the wheel, a knuckle coupled with the wheel, and a lower arm coupled with the knuckle.

As illustrated in FIG. 1, the suspension device 1 includes a spring mechanism 10 and a damping mechanism 20. The spring mechanism 10 is disposed in parallel with the damping mechanism 20.

The spring mechanism 10 connects the sprung member 5 and the unsprung member 6, generates a spring force according to the relative displacement between the sprung member 5 and the unsprung member 6, and causes the spring force to act on the sprung member 5 and on the unsprung member 6. The spring mechanism 10 generates the spring force by, for example, a coil spring 11 (illustrated by a double-dashed line in FIG. 1) mounted on, for example, a piston 22 of the damping mechanism 20 to be described later. The relative displacement between the sprung member 5 and the unsprung member 6 is a relative displacement in the direction where the sprung member 5 approaches or is away from the unsprung member 6 in the expanding and contracting direction of the suspension device 1. Although the expanding and contracting direction is illustrated here assuming that it is a direction along a vertical direction, the expanding and contracting direction may have a predetermined inclination to the vertical direction. The spring mechanism 10 may be configured to be able to variably control a spring coefficient, namely, the spring force.

The damping mechanism 20 connects the sprung member 5 and the unsprung member 6 and generates a damping force for damping the relative movement between the sprung member 5

and the unsprung member 6. The relative movement between the sprung member 5 and the unsprung member 6 is a relative movement in the direction where the sprung member 5 approaches or is away from the unsprung member 6 in the expanding and contracting direction. The damping mechanism 20 damps the relative movement by generating the damping force according to the relative speed between the sprung member 5 and the unsprung member 6 in the relative movement.

As illustrated in FIG. 1, the damping mechanism 20 includes a cylinder 21 connected to one of the sprung member 5 or the unsprung member 6 and sealed with a hydraulic oil (corresponding to a working fluid), a piston 22 having a piston portion 23 reciprocating in the cylinder 21 connected to the other of the sprung member 5 or the unsprung member 6, an oil seal 24, and a lip portion angle changer 26.

The cylinder 21 is formed in a cylindrical shape with both ends open and sealed with the hydraulic oil for generating a fluid resistance by viscosity. The lower opening of the cylinder 21 is closed by a closing member 25, and the upper opening of the cylinder 21 is closed by the oil seal 24. The inside of the cylinder 21 is shut off from the outside thereof by the closing member 25 and the oil seal 24 and the inside of the cylinder 21 are hermetically sealed. The cylinder 21 is covered with a shell 27 except the upper opening thereof. The lower end of the shell 27 is disposed with a bracket 28 attached to the unsprung member 6. In the first embodiment, the cylinder 21 is connected to the unsprung member 6 via the shell 27. The upper end portion of the shell 27 is disposed with a lower spring sheet 29 having the coil spring 11 disposed on the surface thereof.

The piston 22 includes the piston portion 23

accommodated in the cylinder 21 and a piston rod 30 expanding from the piston portion 23 upward. The piston portion 23 is disposed in the cylinder 21 so as to be able to relatively move therein. The piston portion 23 divides the space in the cylinder 21 into a piston upper chamber 31 on the piston portion 23 and a piston lower chamber 32 under the piston portion 23. The piston portion 23 is disposed with a port (not illustrated) through which the hydraulic oil passes and a valve (not illustrated) for opening and closing the port and moves in the cylinder 21 while receiving the fluid resistance of the hydraulic oil generated by the port and the valve. The piston rod 30 expands upward from the piston portion 23 and is caused to pass into the piston upper chamber 31. The upper end portion of the piston rod 30 of the piston 22 projects the outside of the cylinder 21.

The upper end portion of the shell 27 is disposed with a rod guide 33 for passing the piston rod 30 inside thereof. The rod guide 33 projects the piston rod 30 inside of the shell 27 by passing the piston rod 30 inside thereof. The rod guide 33 guides the moving direction of the piston rod 30 by passing it inside thereof so that the piston rod 30 can move along its longitudinal direction. The rod guide 33 includes a small diameter cylindrical portion 37 and a large diameter cylindrical portion 38 having a diameter larger than that of the small diameter cylindrical portion 37 integrally therewith and they are coaxial with each other. The rod guide 33 passes the piston rod 30 inside of the small diameter cylindrical portion 37. The rod guide 33 is attached to the upper end portion of the cylinder 21 and to the upper end portion of the shell 27 by inserting the small diameter cylindrical portion 37 inside of the upper end portion of the cylinder 21 and inserting the

large diameter cylindrical portion 38 inside of the upper end portion of the shell 27.

The oil seal 24 having closed the upper opening of the cylinder 21 passes the piston rod 30 inside thereof. The oil seal 24 overlaps with the rod guide 33 and is inserted inside of the upper end portion of the shell 27. The oil seal 24 passes the piston rod 30 inside thereof and thereby projects the piston rod 30 inside of the cylinder 21. The oil seal 24 passes the piston rod 30 inside thereof so that the oil seal 24 can move along the longitudinal direction of the piston rod 30 and seals the cylinder 21 with the hydraulic oil by suppressing the leakage of the hydraulic oil from between the inner surface of the oil seal 24 and the piston rod 30.

As illustrated in FIG. 2 and FIG. 3, the oil seal 24 includes a core metal 39 composed of metal and a seal portion 40 composed of synthetic resin having elasticity and the outside appearance thereof is formed in an annular shape. The core metal 39 is formed in an annular shape. The seal portion 40 includes integrally therewith an annular portion 41 having the core metal 39 buried therein by insert molding and a cylindrical portion 42 disposed on the inside periphery side of the annular portion 41 integrally therewith and passes the piston rod 30 inside thereof. The upper inside edge of the inner peripheral surface of the cylindrical portion 42 is disposed with a dust lip 43 in contact with the piston rod 30, and the lower inside edge of the inner peripheral surface of the cylindrical portion 42 is disposed with an oil lip 44 (corresponding to the lip portion) in contact with the piston rod 30. The dust lip 43 suppresses foreign substances from entering between the dust lip 43 and the piston rod 30.

The oil lip 44 is formed in a convex chevron shape toward the piston rod 30 in a longitudinal section. The angle α (illustrated in FIG. 4) of a surface 44b (hereinafter, referred to as the lower surface) of the oil lip 44, which is located below an apex 44a of the oil lip 44 in contact with the piston rod 30, to the axial center P of the piston rod 30 is changed by the lip portion angle changer 26. Further, the angle β (illustrated in FIG. 4) of a surface 44c (hereinafter, referred to as the upper surface) of the oil lip 44, which is located above the apex 44a of the oil lip 44, to the axial center P of the piston rod 30 is changed by the lip portion angle changer 26.

The outside periphery of the upper end portion of the shell 27 is attached with a shell side closing member 35 provided with a hole 34 for passing the piston rod 30 therethrough. The shell side closing member 35 projects the piston rod 30 inside of the shell 27 by passing the piston rod 30 in the hole 34. In the first embodiment, the upper end portion of the shell 27 is bent to the inside periphery side so as to overlap on the annular portion 41 of the seal portion 40 of the oil seal 24.

In the first embodiment, the upper end portion of the piston rod 30 is disposed with an upper spring sheet 36 (illustrated by a double-dashed line in FIG. 1) that is attached to the sprung member 5 described above and has the coil spring 11 disposed between it and the lower spring sheet 29. In the first embodiment, the piston 22 is connected to the sprung member 5 via the upper spring sheet 36. The coil spring 11 disposed between the upper spring sheet 36 and the lower spring sheet 29 applies an urging force to the lower spring sheet 29 and the upper spring sheet 36 in a direction where the sheets 29, 36 are separated from each other. Namely, the coil spring 11

applies the urging force in the direction where the piston 22 projects from the cylinder 21 to the sheets 29, 36, thereby applying the urging force in the direction where the suspension device 1 expands.

The lip portion angle changer 26 can change the angle α of the lower surface 44b and the angle β of the upper surface 44c of the oil lip 44. Further, the lip portion angle changer 26 changes the angle α of the lower surface 44b and the angle β of the upper surface 44c of the oil lip 44 based on the moving direction of the sprung member 5. The lip portion angle changer 26 includes a changing disk 45 (illustrated in FIG. 5 and FIG. 6), a motor 46 (illustrated in FIG. 5), and an ECU 63 (illustrated in FIG. 1). The changing disk 45 is composed of metal having elasticity such as spring steel and formed in an annular thin sheet shape. The changing disk 45 is disposed with pressure transmission holes 45a for passing the hydraulic oil therethrough and a cutout portion 45b formed by cutting off a part of the outside edge portion thereof. A shaft 47 having a C-shape when viewed on a plan view is attached to approximately the entire periphery of the outside edge of the changing disk 45 except the cutout portion 45b. The shaft 47 attached to the outside edge of the changing disk 45 is attached to the inside periphery of the large diameter cylindrical portion 38 of the rod guide 33, and the inside edge thereof is attached to the outside periphery of the oil lip 44 of the seal portion 40 of the oil seal 24. Further, the changing disk 45 is disposed in a flexed state between the inside periphery of the large diameter cylindrical portion 38 of the rod guide 33 and the outside periphery of the oil lip 44 of the seal portion 40 of the oil seal 24.

The motor 46 is disposed in the cutout portion 45b of the changing disk 45. The output shaft of the motor 46 is attached to the shaft 47. The motor 46 rotates the shaft 47 in both arrows Ka, Kb (illustrated in FIG. 5) directions about the axis center thereof. When the shaft 47 rotates in the arrow Ka direction, the inside edge of the changing disk 45 rotates in an arrow Kaa (illustrated in FIG. 7 and FIG. 8) direction opposite to the arrow Ka because the changing disk 45 is disposed while being flexed between the large diameter cylindrical portion 38 of the rod guide 33 and the oil lip 44 of the oil seal 24. Since the inside edge of the changing disk 45 is attached to the outside periphery of the oil lip 44 of the oil seal 24, the oil lip 44 rotates downward in the arrow Kaa (illustrated in FIG. 7 and FIG. 8) direction.

When the shaft 47 rotates in the arrow Kb direction, the inside edge of the changing disk 45 rotates in an arrow Kbb (illustrated in FIG. 9 and FIG. 10) direction opposite to the arrow Kb because the changing disk 45 is disposed while being flexed between the large diameter cylindrical portion 38 of the rod guide 33 and the oil lip 44 of the oil seal 24. Since the inside edge of the changing disk 45 is attached to the outside periphery of the oil lip 44 of the oil seal 24, the oil lip 44 rotates in the arrow Kbb (illustrated in FIG. 9 and FIG. 10) direction. When the oil lip 44 rotates upward in the arrows Kaa, Kbb directions, the angles α , β are changed because the seal portion 40 of the oil seal 24 is composed of synthetic resin having elasticity such as rubber. As described above, since the motor 46 rotates the shaft 47 in both the arrows Ka, Kb (illustrated in FIG. 5) directions in response to a command from the ECU 63, it can change the angles α , β .

One set of the ECU 63 is disposed to the plural

suspension devices 1, and when, for example, a vehicle has four wheels, the one set of the ECU 63 is disposed to the four suspension devices 1. The ECU 63 controls the motors 46 of the suspension devices 1 and changes the angles α , β .

The friction force of the damping mechanism 20 to the cylinder 21 when the piston 22 moves is mainly generated by the friction force between the oil seal 24 and the piston rod 30. Since the cylinder 21 is sealed with the hydraulic oil and the piston rod 30 moves with respect to the cylinder 21, an oil film O (illustrated in FIG. 3) composed of the hydraulic oil exists between the oil seal 24 and the piston rod 30. Thus, the friction force between the oil seal 24 and the piston rod 30 is proportional to the thickness of the oil film O, and the thickness of the oil film O affects the angle α of the lower surface 44b and the angle β of the upper surface 44c of the oil seal 24. The thickness of the oil film O when the piston rod 30 moves with respect to the cylinder 21 upward, namely, when the suspension device 1 expands is determined by the angle α . The thickness of the oil film O when the piston rod 30 moves downward with respect to the cylinder 21, namely, when the suspension device 1 contracts is determined by the angle β . An increase of the angles α , β increases the thickness of the oil film O, whereas a decrease of the angles α , β decreases the thickness of the oil film O. Namely, the ECU 63 controls the motors 46 of the respective suspension device 1 and changes the angles α , β , thereby changing the friction force of the oil lip 44 of the oil seal 24 to the piston rod 30.

In the first embodiment, the ECU 63 controls respective portions of the vehicle on which the suspension devices 1 are mounted. The ECU 63 is an electronic circuit

mainly composed of a known microcomputer including a CPU, ROM, RAM, and an interface.

The ECU 63 electrically connects various sensors such as an sprung G sensor 72 as an upper-spring acceleration detector, an unsprung G sensor 73 as an unsprung acceleration detector and the suspension device 1 to the respective portions of the vehicle. The sprung G sensor 72 is disposed to the sprung member 5. The sprung G sensor 72 detects the acceleration of the sprung member 5 in a vertical direction, typically, the acceleration of the suspension device 1 in an expanding and contracting direction (hereinafter, called "sprung acceleration"). In the first embodiment, three sets of the sprung G sensors 72 are disposed at at least three positions of the vehicle body as the sprung members 5, respectively. The unsprung G sensor 73 is disposed to the unsprung member 6. The unsprung G sensor 73 detects the acceleration of the unsprung member 6 in the vertical direction, typically, the acceleration of the suspension device 1 in the expanding and contracting direction (hereinafter, called "unsprung acceleration"). The ECU 63 is input with electric signals (detection signals) corresponding to the results of detection from the various sensors, outputs drive signals to the suspension device 1 and the respective portions of the vehicle according to the results of detection and controls the drive thereof the portions.

Next, the operation of the suspension device 1 according to the first embodiment will be explained based on drawings. FIG. 11 illustrates an example of a flowchart for causing the ECU of the suspension device according to the first embodiment of the present invention to change the angle of an oil lip of the oil seal, FIG. 12 is a view explaining the operation when the wheel of the suspension

device according to the first embodiment of the present invention gets over a convex portion of a road surface, and FIG. 13 is a view explaining the angle of the oil lip of the oil seal when the wheel illustrated in FIG. 12 gets over the convex portion of the road surface.

When the vehicle travels, the suspension device 1 operates according to the travel state of the vehicle and the state of the road surface. For example, as illustrated in FIG. 12, when the wheel that configures the unsprung member 6 gets over the convex portion C of the road surface, an upward force is applied to the wheel from the convex portion C. The upward force applied to the wheel is input to the shell 27 via the knuckle. Since the shell 27 is urged downward from the coil spring 11 via the lower spring sheet 29, a part of the upward force input to the shell 27 is cancelled by the urging force of the coil spring 11, and the remaining force presses and contracts the coil spring 11. The contraction of the coil spring 11 moves the shell 27 upward together with the cylinder 21 to which the shell 27 is attached so that the overall length of the suspension device 1 becomes short and the sprung member 5 moves upward as illustrated in FIG. 12(a). At the time, the piston 22 moves downward in the cylinder 21. FIG. 12(a) illustrates the excitation region in which the upward force having acted on the wheel acts on the suspension device 1.

Thereafter, although the force for contracting the coil spring 11 acts thereon, an expansion of the coil spring 11 by an elastic restoring force causes the resultant force of the upward force input to the shell 27 and the elastic restoring force of the coil spring 11 to act on the sprung member 5. As a result, as illustrated in FIG. 12(b), the sprung member 5 moves upward with respect to the cylinder 21 together with the piston 22, the

suspension device 1 expands, and the sprung member 5 moves upward. FIG. 12(b) illustrates the vibration control region of the suspension device 1 in which the movement of the sprung member 5 is regulated by the upward force acting on the wheel.

When the wheel has passed the apex of the convex portion C of the road surface, the upward force from the road surface to the wheel is removed and thereby the force for contracting the coil spring 11 is removed. Since a downward force acts on the sprung member 5 by gravity and a contracting force is removed, the coil spring 11 expands and the cylinder 21 and the shell 27 move downward relatively with respect to the piston 22. As illustrated in FIG. 12(c), the expansion of the coil spring 11 increases the overall length of the suspension device 1 and moves the sprung member 5 downward. At the time, the piston 22 moves in the cylinder 21 upward. FIG. 12(c) illustrates the excitation region of the suspension device 1 in which the upward force having acted on the wheel is removed.

Thereafter, when the wheel has gotten over the convex portion C of the road surface, the upward force from the road surface to the wheel is removed, a downward force acts on the sprung member 5 by gravity, and the coil spring 11 is contracted by the elastic restoring force. As illustrated in FIG. 12(d), the cylinder 21 moves upward with respect to the piston 22, and the suspension device 1 contracts. Since the upward force from the road surface to the wheel is removed and the downward force acts on the sprung member 5 by gravity, the sprung member 5 moves downward. FIG. 12(d) illustrates the vibration control region of the suspension device 1 in which the movement of the sprung member 5 is regulated by the elastic restoring

force of the coil spring 11. As described above, in the suspension device 1, when the wheel gets over the convex portion C of the road surface, the expansion and contraction of the coil spring 11 suppress vibration.

The expansion and contraction of the coil spring 11 of the suspension device 1 move the piston 22 in the cylinder 21. Since the hydraulic oil is sealed in the cylinder 21, the piston 22 moves in the cylinder 21 while receiving the fluid resistance of the hydraulic oil. Thus, the piston 22 moves in the cylinder 21 at a speed slower than when no hydraulic oil is sealed in the cylinder 21. When the coil spring 11 of the suspension device 1 expands and contracts, the piston 22 moves in the cylinder 21 while receiving the fluid resistance of the hydraulic oil. With the operation, the damping mechanism 20 generates the damping force according to the expanding/contracting speed of the coil spring 11, namely, according to the relative speed between the sprung member 5 and the unsprung member 6, thereby damping the relative movement between the sprung member 5 and the unsprung member 6, namely, the expansion and contraction of the coil spring 11.

Since the piston rod 30 of the piston 22 is passed in the piston upper chamber 31, the fluid resistance of the hydraulic oil received by the piston 22 when it moves in the cylinder 21 upward is larger than that received by the piston 22 when it moves in the cylinder 21 downward. Thus, the damping force when the suspension device 1 contracts becomes larger than that when it expands.

As described above, in the excitation region illustrated in FIG. 12(a), the suspension device 1 is made likely to contract, and in the vibration control region illustrated in FIG. 12(b), the suspension device 1 is made unlikely to expand. Further, in the excitation region

illustrated in FIG. 12(c), the suspension device 1 is made likely to expand, and in the vibration control region illustrated in FIG. 12(d), the suspension device 1 is made unlikely to contract, which allows to carry out Sky-Hook control for keeping the sprung member 5 in a stable attitude at all times.

Next, an example of control carried out by the ECU 63 of the suspension device 1 according to the first embodiment will be explained based on the flowchart illustrated in FIG. 11. The ECU carries out the control for changing the friction force of the oil seal 24 by changing the angles α , β of the oil lip 44 of the oil seal 24. The control routine illustrated in the flowchart illustrated in FIG. 11 is repeated at a control cycle of several milliseconds to several tens of milliseconds.

First, the ECU 63 calculates the acceleration of the sprung member 5 immediately above the suspension device 1 based on the results of detection of the sprung G sensors 72 disposed at at least the three positions (step ST11). After step ST11, the ECU 63 integrates the acceleration of the sprung member 5 calculated at step ST11 and calculates the speed of the sprung member 5 (step ST12). After step ST12, the ECU 63 determines whether the sprung member 5 moves downward or upward or the sprung member 5 is at rest based on the speed of the sprung member 5 calculated at step ST12 (step ST13).

When the ECU 63 determines that the upward/downward speed of the sprung member 5 calculated at step ST12 is, for example, equal to or less than a predetermined low speed, it determines that the sprung member 5 is at rest, and a process goes to step ST16. The ECU 63 places the oil lip 44 in a neutral state in which the shaft 47 is not rotated in any of the arrows Ka, Kb directions by the motor

46 (step ST16).

Further, when the ECU 63 determines that the speed of the sprung member 5 calculated at step ST12 exceeds the predetermined speed downward, it determines that the sprung member 5 moves downward, and the process goes to step ST14. The ECU 63 rotates the shaft 47 in the arrow Ka direction from the neutral state by the motor 46 and rotates the oil lip 44 downward from the neutral state, thereby increasing the angle α and decreasing the angle β (step ST14). When the sprung member 5 moves downward as illustrated in FIG. 12(c) and FIG. 12(d) as described above, the ECU 63 increases the angle α and decreases the angle β as illustrated in FIG. 13(c) and FIG. 13(d). In the excitation region illustrated in FIG. 12(c), the ECU 63 increases the thickness of the oil film O by increasing the angle α so that the suspension device 1 is likely to expand. Further, in the vibration control region illustrated in FIG. 12(d), the ECU 63 decreases the thickness of the oil film O by decreasing the angle β so that the suspension device 1 is unlikely to contract.

When the ECU 63 determines that the speed of the sprung member 5 calculated at step ST12 exceeds the predetermined speed upward, it determines that the sprung member 5 moves upward, and the process goes to step ST15. The ECU 63 rotates the shaft 47 in the arrow Kb direction from the neutral state by the motor 46 and rotates the oil lip 44 upward from the neutral state, thereby decreasing the angle α and increasing the angle β (step ST15). When the sprung member 5 moves upward as illustrated in FIG. 12(a) and FIG. 12(b) as described above, the ECU 63 decreases the angle α and increases the angle β as illustrated in FIG. 13(a) and FIG. 13(b). In the

excitation region illustrated in FIG. 12(a), the ECU 63 increases the thickness of the oil film O by increasing the angle β so that the suspension device 1 is likely to contract. Further, in the vibration control region illustrated in FIG. 12(b), the ECU 63 makes the suspension device 1 to unlikely expand by decreasing the thickness of the oil film O by decreasing the angle α .

In the suspension device 1 according to the first embodiment, the lip portion angle changer 26 changes the thickness of the oil film O on the piston rod 30 by changing the angles α , β of the oil lip 44, thereby changing the friction force of the oil seal 24 to the piston rod 30. As described above, even if the changing range of the friction force of the oil seal 24 to the piston rod 30 is increased, since the lip portion angle changer 26 changes the angles α , β of the oil lip 44 by rotating the shaft 47 about the axis center, the increase of size of the lip portion angle changer 26 can be suppressed. Since the changing range of the friction force of the piston rod 30 can be increased while achieving downsizing, riding comfort when the vehicle travels can be more improved.

Further, in the suspension device 1, the lip portion angle changer 26 changes the angles α , β of the oil lip 44 based on the moving direction of the sprung member 5. The suspension device 1 is made likely to contract in the excitation region illustrated in FIG. 12(a) and made unlikely to expand in the vibration control region illustrated in FIG. 12(b). Further, the suspension device 1 is made likely to expand in the excitation region illustrated in FIG. 12(c) and made likely to contract in the vibration control region illustrated in FIG. 12(d). As

described above, in the excitation region illustrated in FIG. 12(a) and FIG. 12(c), the piston rod 30 is made likely to move, whereas in the vibration control region illustrated in FIG. 12(b) and FIG. 12(d), the piston rod 30 is made unlikely to move. Thus, the suspension device 1 can keep the sprung member 5 in the stable attitude at all times so that a Sky-Hook effect can be obtained.

Second Embodiment

A suspension device 1 of a second embodiment according to the present invention will be explained based on FIG. 14 to FIG. 19. FIG. 14 is a longitudinal sectional view illustrating a configuration of a main portion of an oil seal of the suspension device according to the second embodiment, FIG. 15 is a longitudinal sectional view illustrating a XIV portion in FIG. 14 in enlargement, FIG. 16 is a longitudinal sectional view illustrating the state that the angle α of an oil lip of the oil seal of the suspension device according to the second embodiment is decreased, FIG. 17 is a view illustrating the surface pressure of the oil seal of FIG. 16 in the axis center direction of the oil lip, FIG. 18 is a longitudinal sectional view illustrating the state that the angle β of the oil lip of the oil seal of the suspension device according to the second embodiment is decreased, and FIG. 19 is a view illustrating the surface pressure of the oil seal of FIG. 18 in the axis center direction of the oil lip. In FIG. 14 to FIG. 18, the same components as those of the first embodiment are denoted by the same reference numerals and the explanation thereof is omitted.

As illustrated in FIG. 14, in the second embodiment, the oil seal 24 of the suspension device 1 includes a second oil lip 51 having a chevron-shaped cross section and disposed to a central portion in an axial center P

direction. Further, a lip portion angle changer 26 of the suspension device 1 changes the angles α , β of the oil lip 44 according to the moving direction of a piston rod 30 to a cylinder 21. As illustrated in FIG. 14 and FIG. 15, the lip portion angle changer 26 includes a contraction change ring member 52 (corresponding to a lip upper portion angle changer) and an expansion change ring member 53 (corresponding to a lip lower portion angle changer). The contraction change ring member 52 changes the angle β and is disposed above the apex 44a of the oil lip 44. The expansion change ring member 53 changes the angle α and is disposed below the apex 44a of the oil lip 44. Further, the contraction change ring member 52 and the expansion change ring member 53 are composed of a piezoelectric element, buried in the oil seal 24 by insert molding, and formed in an annular shape coaxially with the oil seal 24.

An application of the contraction change ring member 52 in response to a command from an ECU 63 increases the cross-sectional area of the oil seal 24 on the longitudinal cross-sectional surface thereof so that the angle β is made smaller than a neutral state before the contraction change ring member 52 is applied as illustrated in FIG. 18. When the contraction change ring member 52 makes the angle β small, the surface pressure of the oil lip 44 to the piston rod 30 is maximized at a position upward of the apex 44a of the oil lip 44 as illustrated in FIG. 19, which makes the suspension device 1 unlikely to contract.

An application of the expansion change ring member 53 in response to a command from the ECU 63 increases the cross-sectional area of the oil seal 24 on the longitudinal cross-sectional surface thereof so that the angle α is made smaller than a neutral state before the expansion

change ring member 53 is applied as illustrated in FIG. 16. When the expansion change ring member 53 makes the angle α small, the surface pressure of the oil lip 44 to the piston rod 30 is maximized at a position downward of the apex 44a of the oil lip 44 as illustrated in FIG. 17, which makes the suspension device 1 unlikely to expand. The horizontal axes of FIG. 17 and FIG. 19 illustrate the surface pressure of the oil lip 44 to the piston rod 30 and the vertical axes thereof illustrate the position of the oil lip 44 in the axial center P direction. The single-dashed lines of FIG. 17 and FIG. 19 illustrate the position of the apex 44a.

Next, an example of control carried out by the ECU 63 of the suspension device 1 according to the second embodiment will be explained based on a flowchart illustrated in FIG. 20. The ECU carries out the control to change the friction force of the oil seal 24 by changing the angles α , β of the oil lip 44 of the oil seal 24. FIG. 20 illustrates an example of the flowchart for changing the angles of the oil lip of the oil seal by the ECU of the suspension device according to the second embodiment of the present invention. The control routine illustrated in the flowchart illustrated in FIG. 20 is repeated at a control cycle of several milliseconds to several tens of milliseconds.

First, the ECU 63 calculates the acceleration of a sprung member 5 based on the results of detection of sprung G sensors 72 disposed at at least three positions and calculates the speed of the sprung member 5 by integrating the calculated acceleration of the sprung member 5 (step ST21). In the second embodiment, a sensor for calculating the speed of the sprung member 5 may be disposed to a vehicle body and the result of detection of the sensor may be used. After step ST21, the ECU 63 calculates the

acceleration of the unsprung member 6 based on the result of detection of the unsprung G sensor 73 and calculates the speed of the unsprung member 6 by integrating the calculated acceleration of the unsprung member 6, thereby estimating whether the suspension device 1 expands or contracts (step ST22). When the ECU 63 determines that the suspension device 1 expands, it decreases the angle α by applying the expansion change ring member 53 and not applying the contraction change ring member 52 (step ST23). When the piston rod 30 moves upward with respect to the cylinder 21, the ECU 63 makes the suspension device 1 unlikely to expand by decreasing the thickness of the oil film O by causing the expansion change ring member 53 to decrease the angle α .

Further, when the ECU 63 determines that the suspension device 1 contracts, it decreases the angle β by carrying out the application to the contraction change ring member 52 and not carrying out the application to the expansion change ring member 53 (step ST24). As described above, when the piston rod 30 moves downward with respect to the cylinder 21, the ECU 63 makes the suspension device 1 unlikely to expand by decreasing the thickness of the oil film O by causing the contraction change ring member 52 to decrease the angle β .

The suspension device 1 according to the second embodiment changes the thickness of the oil film O on the piston rod 30 by causing the lip portion angle changer 26 to change the angles α , β of the oil lip 44, thereby changing the friction force of the oil seal 24 to the piston rod 30. Thus, since the suspension device 1 according to the second embodiment can increase the changing range of the friction force of the piston rod 30

while achieving downsizing likewise the suspension device 1 according to the first embodiment, riding comfort when the vehicle travels can be more improved.

In the suspension device 1 according to the second embodiment, the lip portion angle changer 26 includes the expansion change ring member 53 and the contraction change ring member 52 and can change the angle α of the lower surface 44b and the angle β of the upper surface 44c of the oil lip 44. Thus, the thickness of the oil film 0 on the piston rod 30, namely, the friction force of the piston rod 30 can be independently changed depending on the expanded state and the contracted state of the suspension device 1.

Further, when the suspension device 1 expands, the suspension device 1 according to the second embodiment makes the suspension device 1 unlikely to expand by decreasing the angle α . When the suspension device 1 contracts, the suspension device 1 according to the second embodiment makes the suspension device 1 unlikely to contract by decreasing the angle β . As described above, since the suspension device 1 according to the second embodiment makes the suspension device 1 unlikely to expand when the suspension device 1 expands and makes the suspension device 1 unlikely to contract when the suspension device 1 contracts, the riding comfort and steering stability can be achieved at the same time.

The suspension device 1 according to the embodiments of the present invention is not limited to the suspension devices of the embodiments and can be variously modified within the scope disclosed in the claims. Although it is described above that the ECU 63 is used also as the ECU for controlling the vehicle in its entirety, the ECU 63 is not limited thereto. For example, the ECU 63 may be configured

independently of the ECU for controlling the vehicle in its entirety. Further, the embodiments of the present invention are not limited to the flowcharts illustrated in FIG. 11 and FIG. 20.

Reference Signs List

- 1 suspension device
- 5 sprung member
- 21 cylinder
- 22 piston
- 24 oil seal
- 26 lip portion angle changer
- 30 piston rod
- 44 oil lip (lip portion)
- 44b lower surface (surface)
- 44c upper surface (surface)
- 52 contraction change ring member (lip upper portion angle changer)
- 53 expansion change ring member (lip lower portion angle changer)
- P axis center
- α angle
- β angle

CLAIMS

1. A suspension device comprising:

an oil seal that configured to seal working fluid in a cylinder and include a lip portion in contact with a piston rod of a piston; and

a lip portion angle changer capable of changing an angle of a surface of the lip portion to an axis center of the piston rod.

2. The suspension device according to claim 1, wherein, the lip portion angle changer changes the angle of a surface of the lip portion to the axis center of the piston rod based on a moving direction of a sprung member.

3. The suspension device according to claim 2, wherein, when the sprung member moves upward, the lip portion angle changer increases the angle of the upper surface of the lip portion to the piston rod and decreases the angle of the lower surface of the lip portion to the piston rod, and

when the sprung member moves downward, the lip portion angle changer decreases the angle of the upper surface of the surface of the lip portion to the piston rod and increases the angle of the lower surface of the surface of the lip portion to the piston rod.

4. The suspension device according to claim 1, wherein, the lip portion angle changer includes

a lip upper portion angle changer that changes the angle of the upper surface of the surface of the lip portion to the piston rod, and

a lip lower portion angle changer that changes the angle of the lower surface of the surface of the lip

portion to the piston rod, and wherein,

the lip portion angle changer changes the angle of the upper surface of the lip portion and the angle of the lower surface of the lip portion according to the moving direction of the piston rod to the cylinder.

5. The suspension device according to claim 4, wherein, when the piston rod moves upward with respect to the cylinder, the lip portion angle changer causes the lip lower portion angle changer to decrease the angle of the lower surface to the piston rod, and

when the piston rod moves downward to the cylinder, the lip portion angle changer causes the lip upper portion angle changer to decrease the angle of the upper surface to the piston rod.

FIG.1

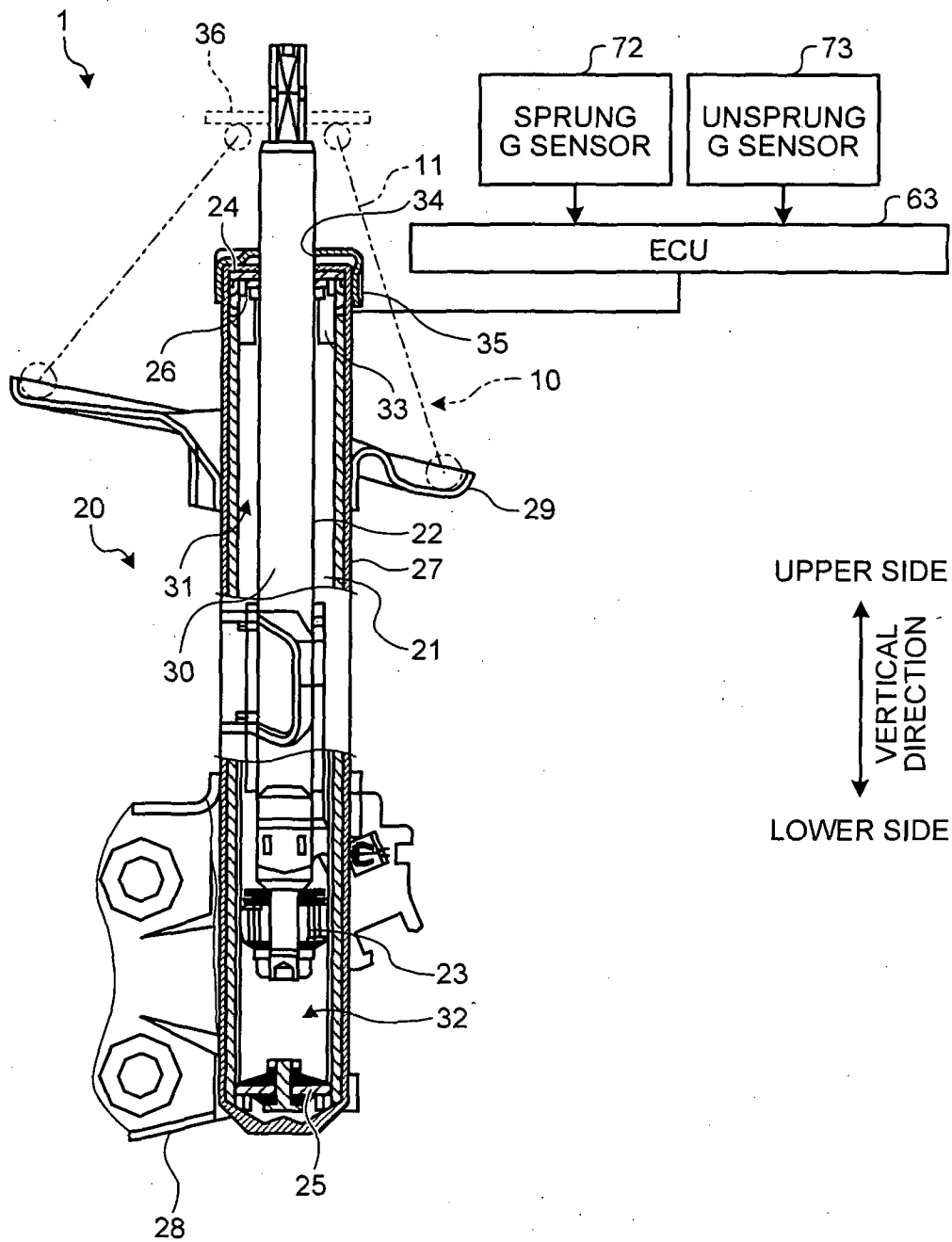


FIG.2

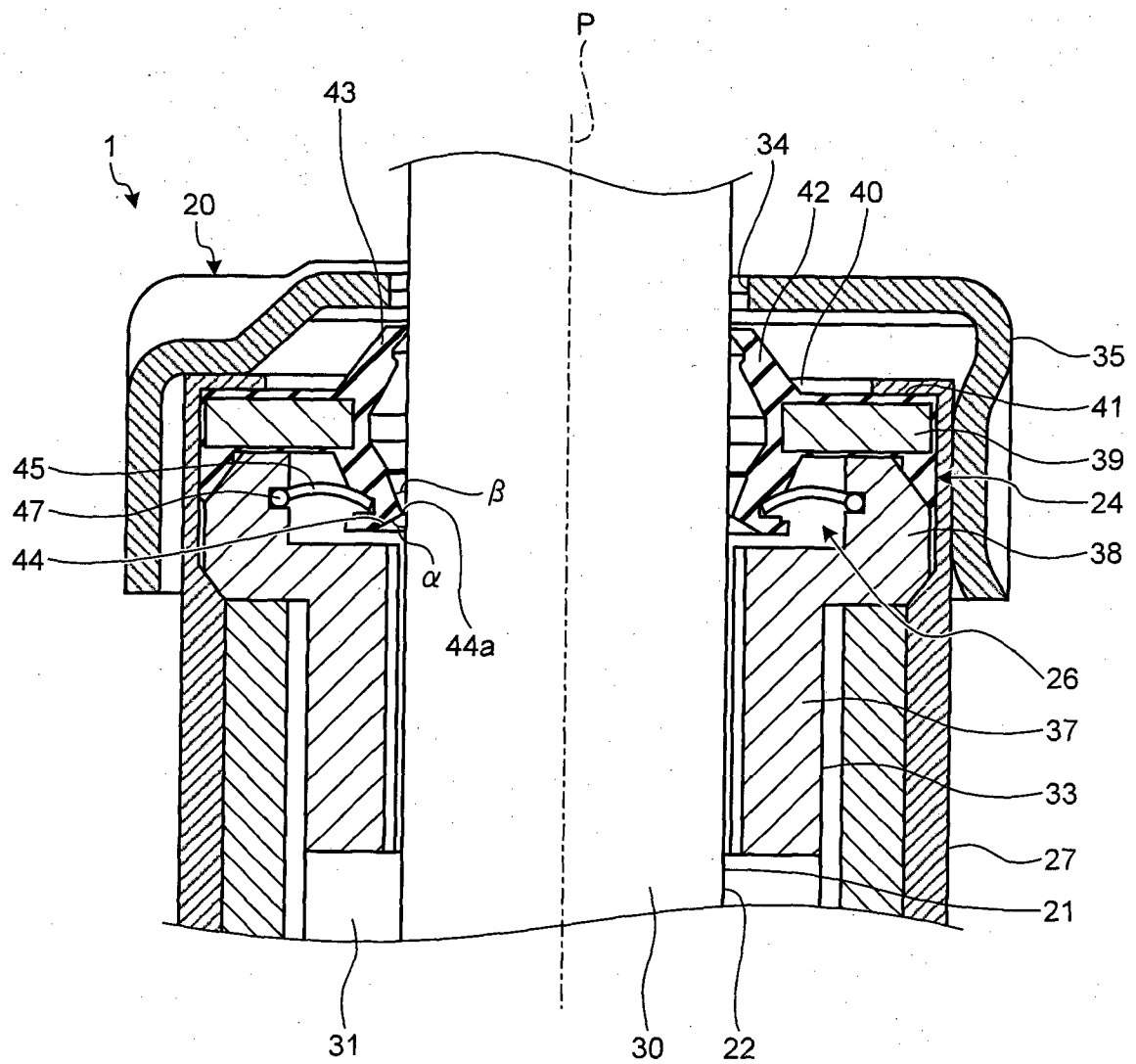


FIG.3

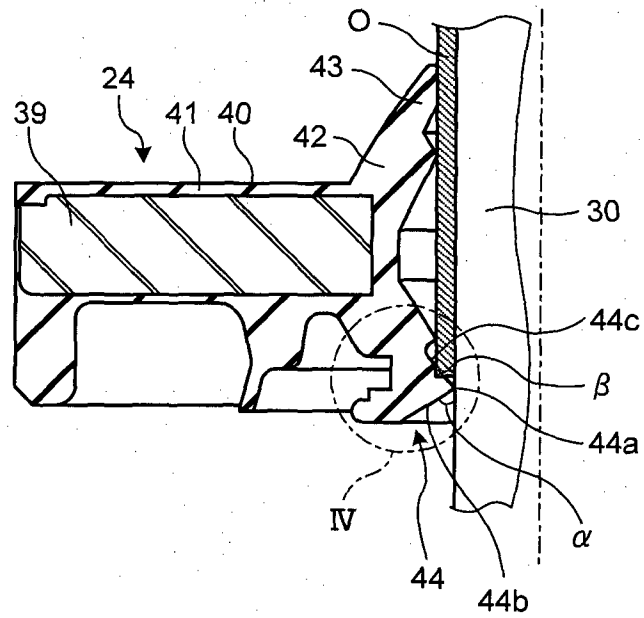
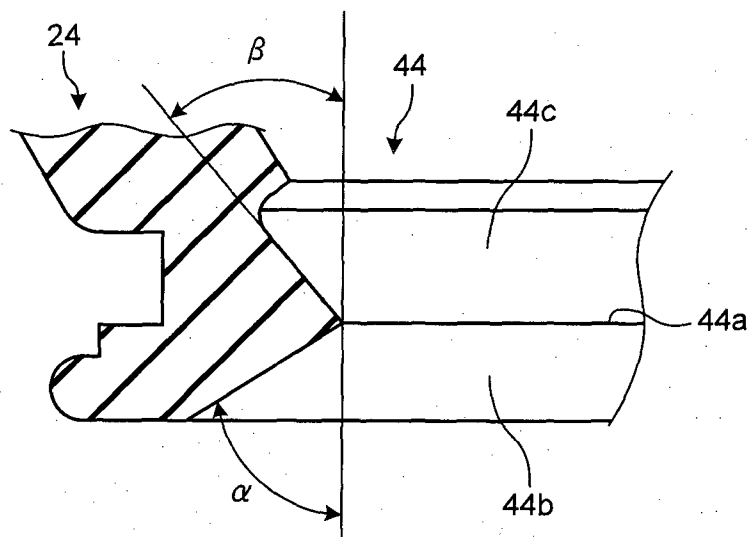


FIG.4



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FIG.5

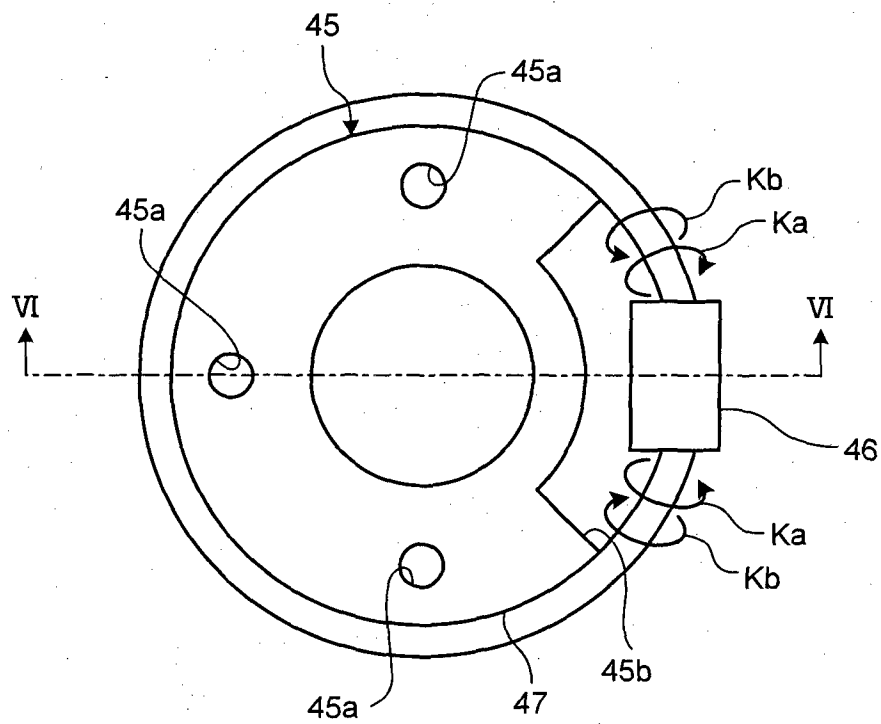


FIG.6

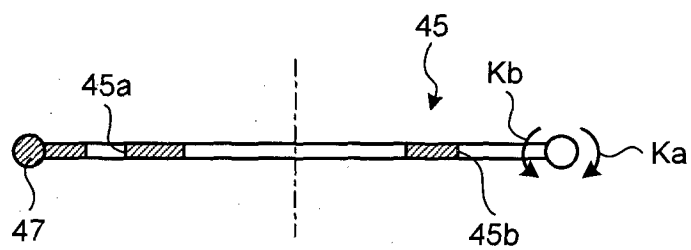


FIG.7

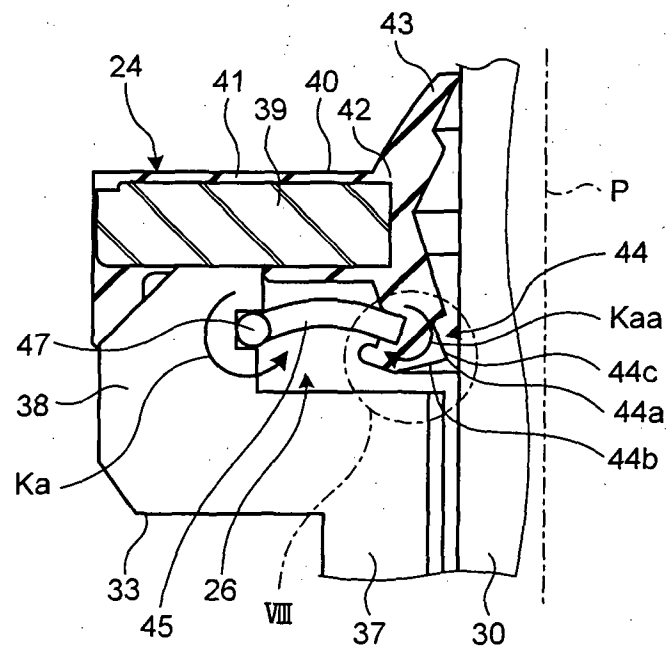


FIG.8

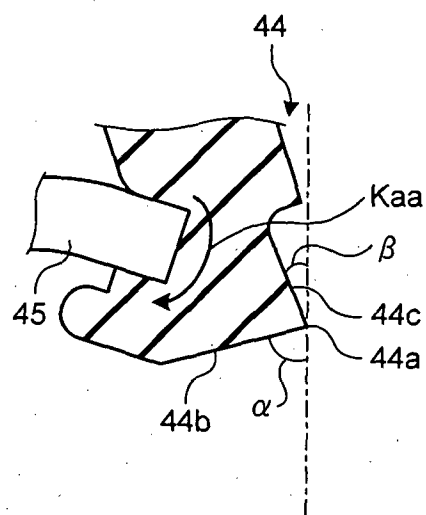


FIG.9

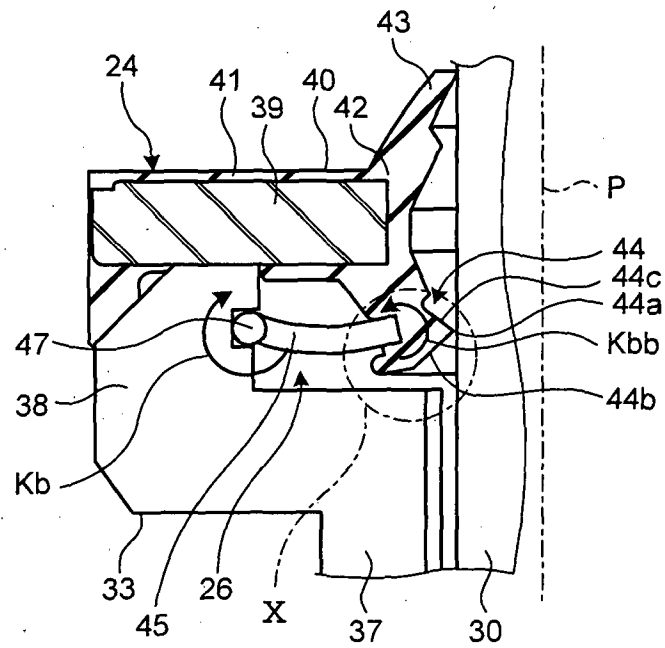
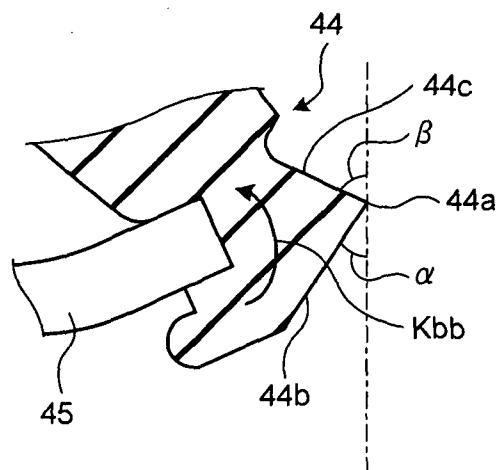


FIG.10



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FIG.11

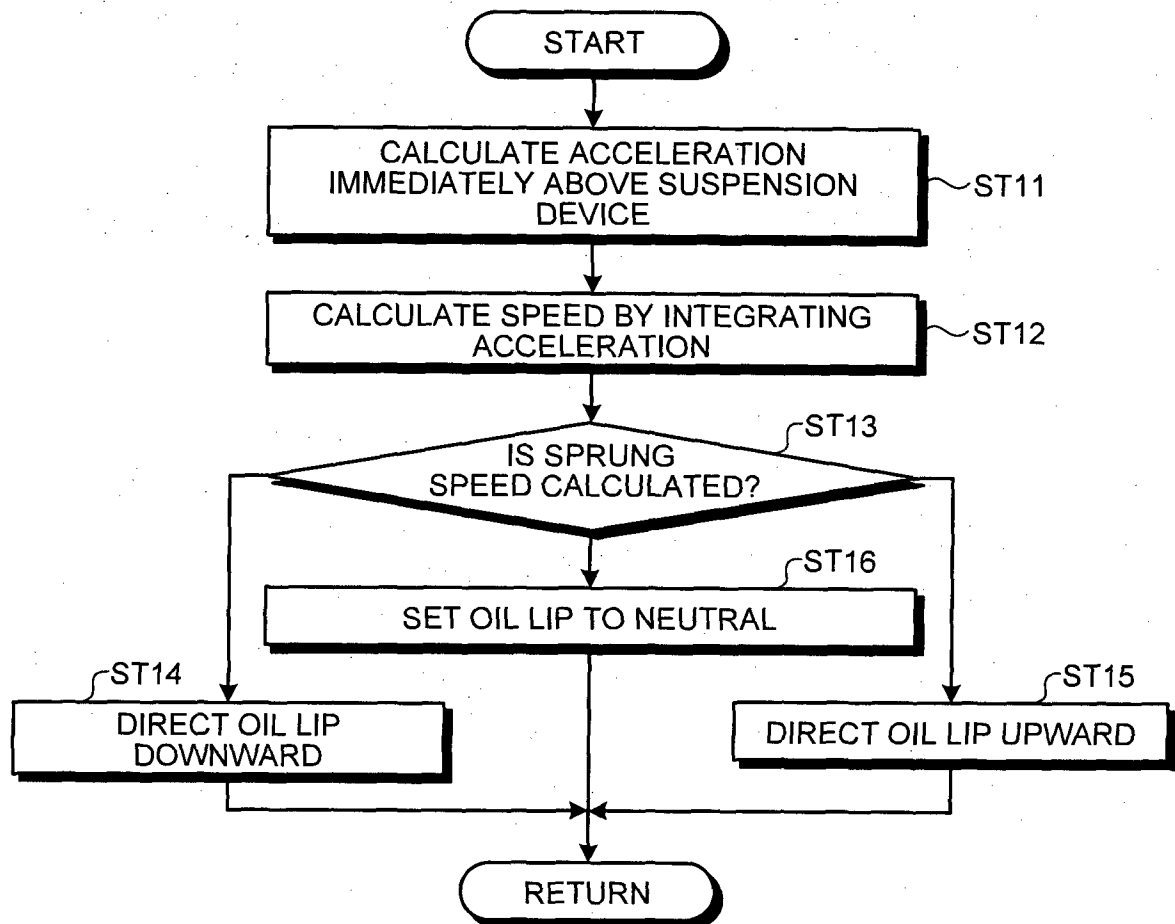


FIG.12

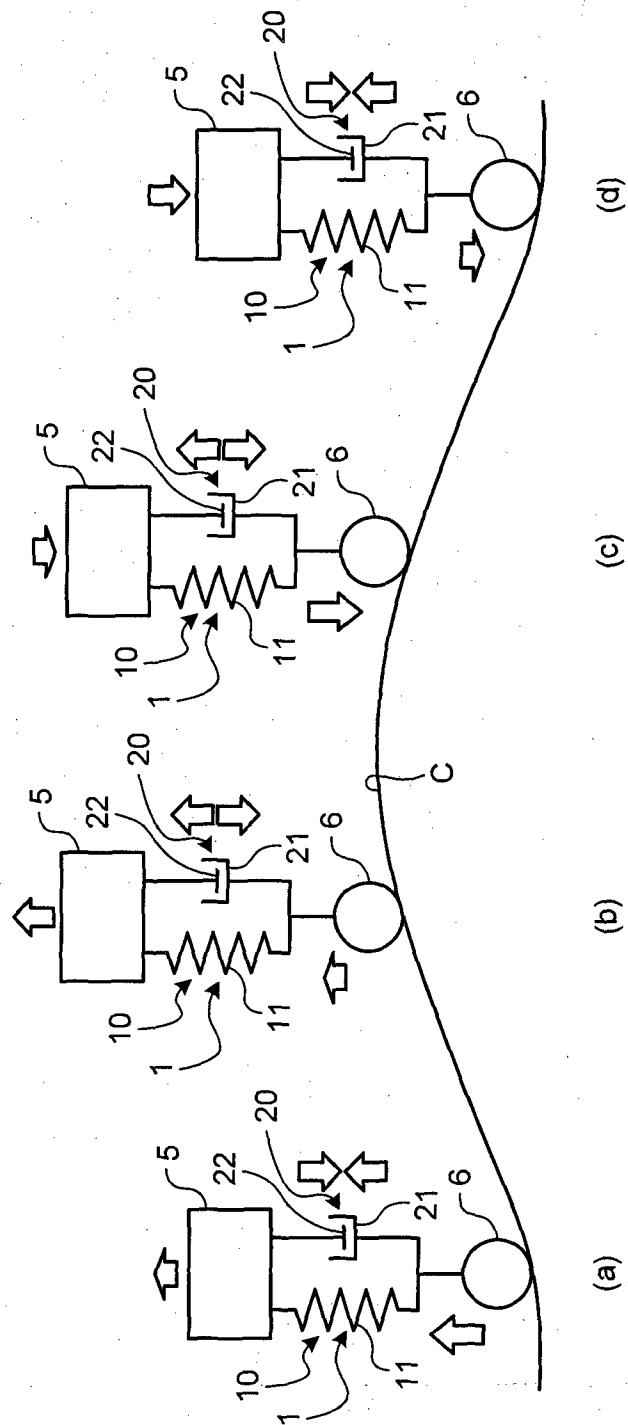
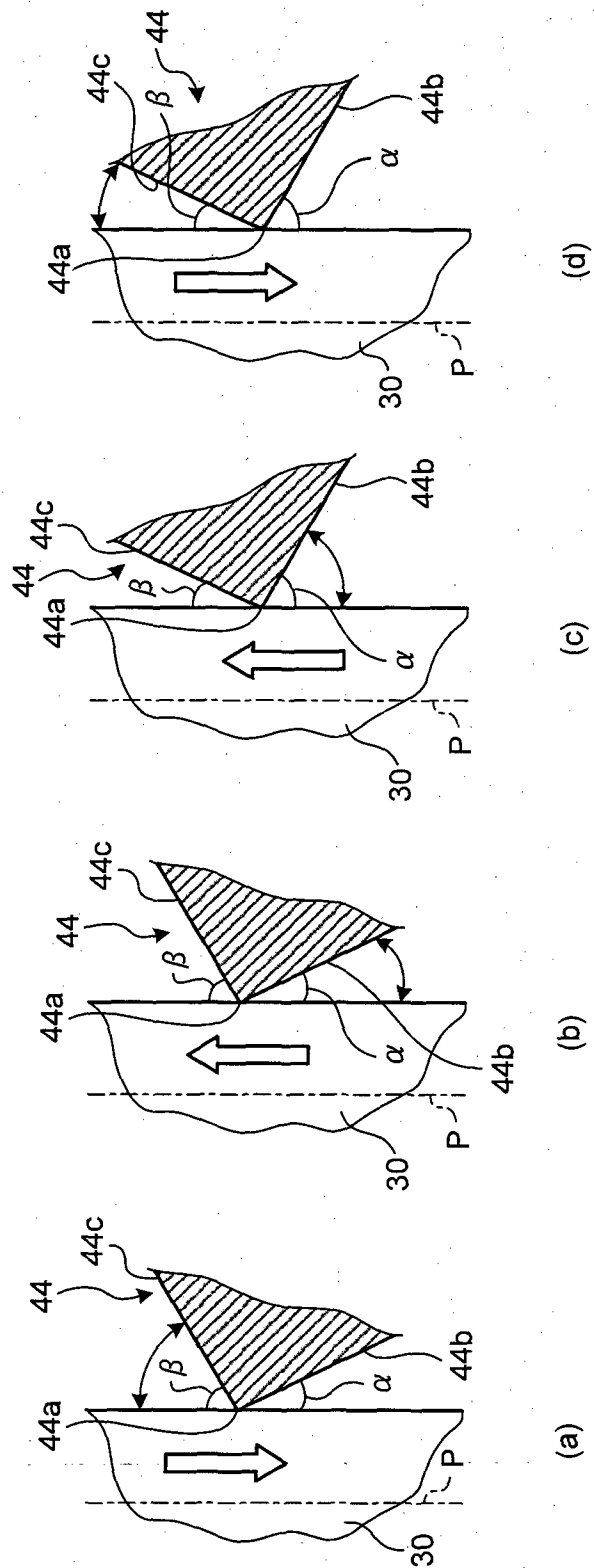


FIG.13



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FIG.14

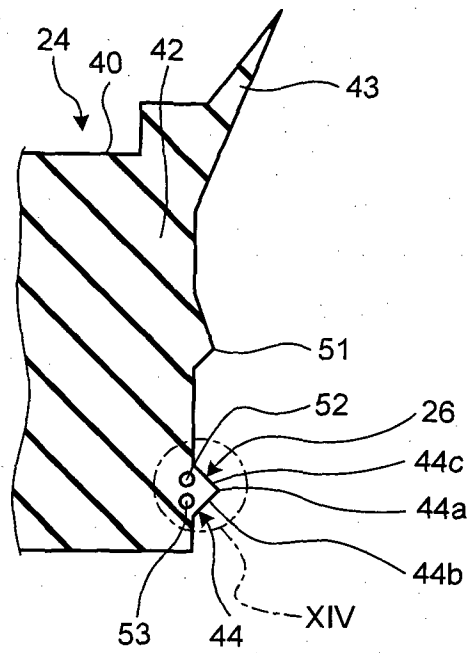
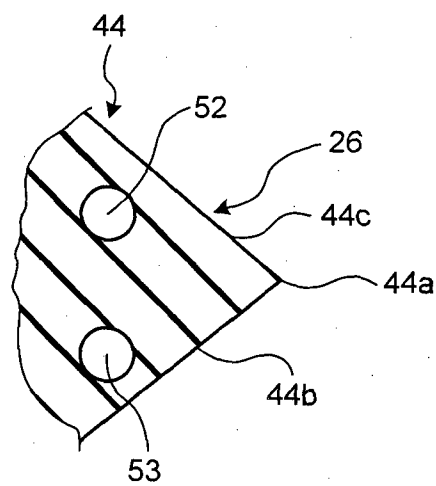


FIG.15



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FIG.16

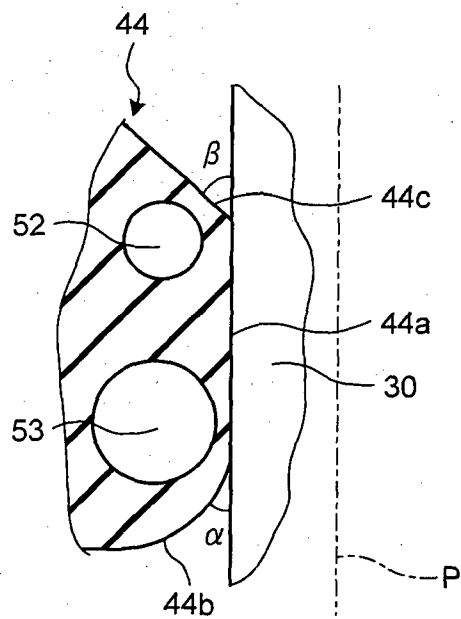
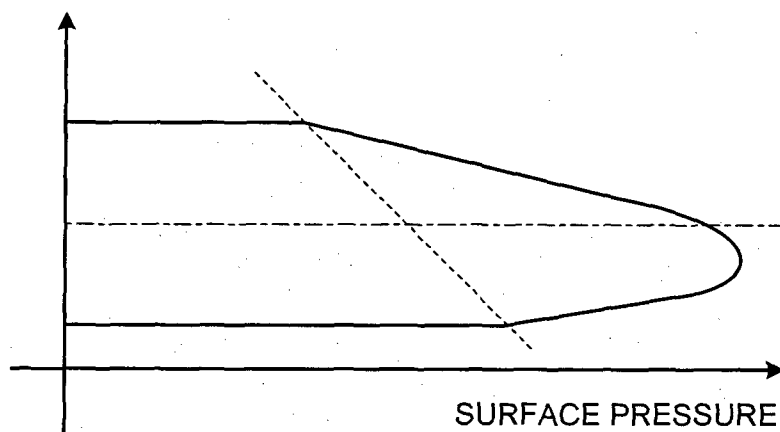


FIG.17



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FIG.18

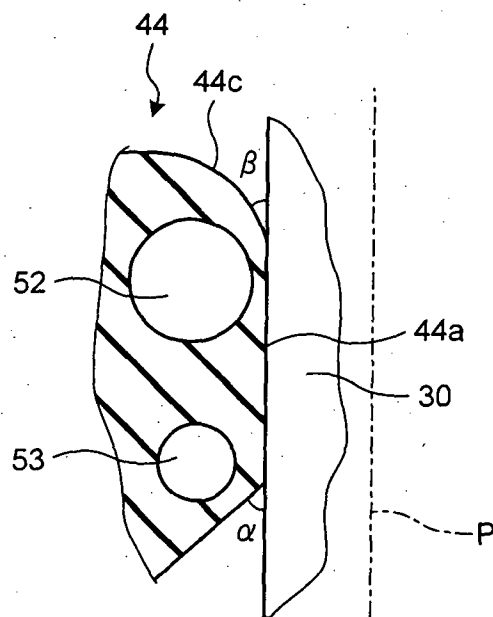


FIG.19

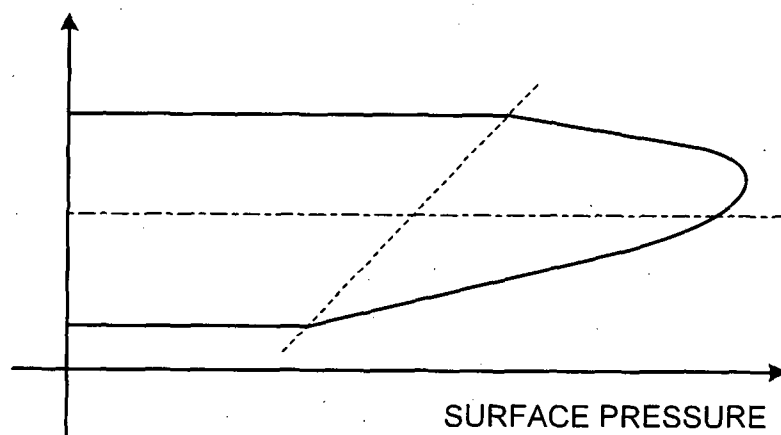
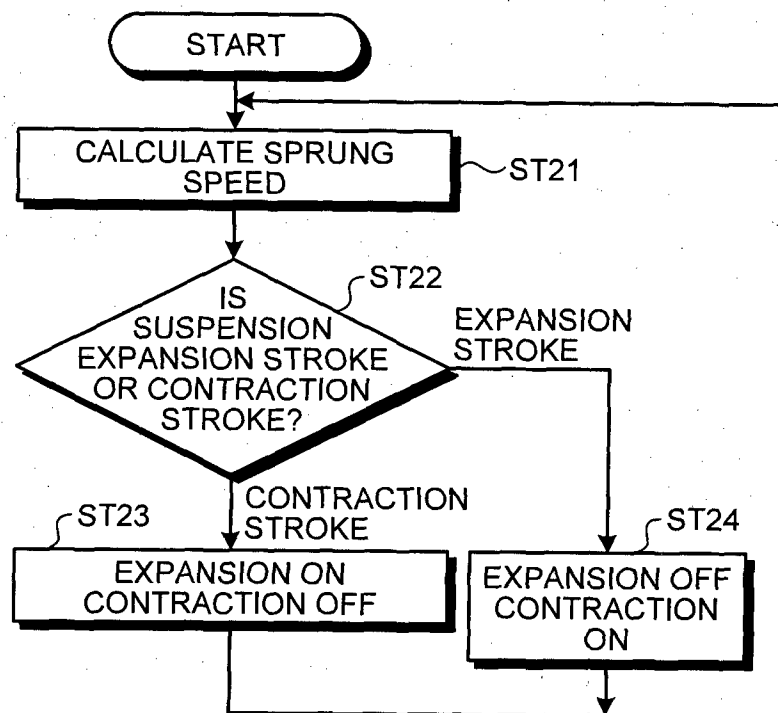


FIG.20



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2013/083539

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16J15/16 B60G17/08 F16F9/36 F16F7/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16J B60G F16F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 098 748 A2 (KAYABA INDUSTRY CO LTD [JP]) 9 September 2009 (2009-09-09) paragraphs [0023], [0026]; figure 1	1-3
X	GB 2 392 482 A (VISTEON GLOBAL TECH INC [US]) 3 March 2004 (2004-03-03) figure 3b claim 28	1-3
A	JP S62 63438 U (UNKNOWN) 20 April 1987 (1987-04-20) figure 1	1



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

4 March 2014

Date of mailing of the international search report

11/03/2014

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Authorized officer

Beaumont, Arnaud

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2013/083539

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