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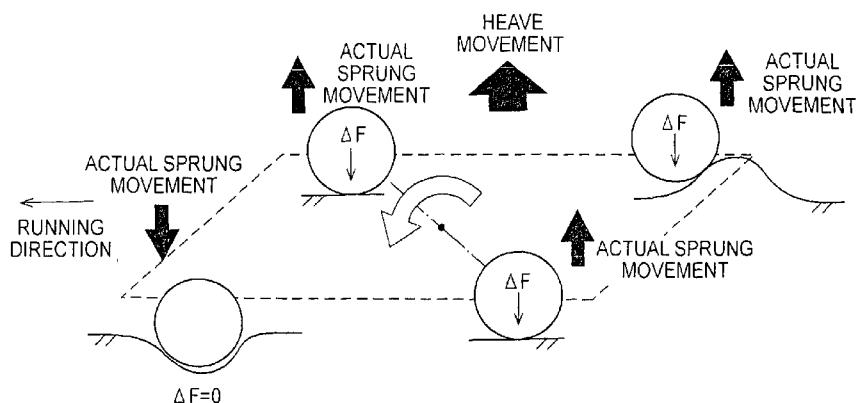
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(54) Title: VEHICLE SUSPENSION SYSTEM

FIG. 1



(57) Abstract: In order to suppress a vehicle body behavior component as a component of vehicle body behavior, a correction value is calculated for only a shock absorber, in which (i) the direction of the actual movement in the vertical direction and (ii) the direction of the movement, in the vertical direction when the Vehicle body behavior based on the vehicle body behavior component is assumed are parallel to each other in a sprung portion, out of plural shock absorbers disposed to vehicle wheels, a reference damping force determined on the basis of a predetermined control rule is corrected, and a target damping force of the respective shock absorbers is determined.

VEHICLE SUSPENSION SYSTEM

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The present invention relates to a vehicle suspension system.

2. Description of Related Art

[0002] Japanese Patent Application Publication No. 10-324129 (JP 10-324129 A)
10 describes a vehicle suspension system including a shock absorber that has a damping force
changing mechanism changing the magnitude of a damping force for relative movement of
a sprung portion and an unsprung portion and that generates the damping force for the
relative movement of the sprung portion and the unsprung portion so as to change the
magnitude thereof. A technique described in JP 10-324129 A is known as the technique
15 of controlling the damping force changing mechanism so as to control the damping force.
Under the understanding that the behavior of a vehicle body is generated by a combination
of a heave, a roll, and a pitch, the vehicle suspension system described in JP 10-324129 A
can calculate a damping force for each shock absorber by calculating damping forces for
suppressing the heave, the roll, and the pitch, dividing the damping forces of the vehicle
20 body behavior into the shock absorbers corresponding to the respective vehicle wheels, and
adding the damping forces.

SUMMARY OF THE INVENTION

[0003] However, the generable range of the damping force generated by each
25 shock absorber is limited. Accordingly, in the suspension system described in JP
10-324129 A, the damping force to actually be generated is corrected from the calculated
damping force into the generable range. That is, in the suspension system described in JP
10-324129 A, although a damping force of each shock absorber is calculated through
complex computation, the damping force to actually be generated is connected into the

generable range and a satisfactory control effect may not be achieved. The invention provides a vehicle suspension system capable of suppressing the behavior of a vehicle body with a relatively simple technique.

[0004] A vehicle suspension system according to an aspect of the invention includes: a plurality of shock absorbers that is disposed to correspond to a plurality of vehicle wheels, that each has a damping force changing mechanism changing the magnitude of a damping force, and that generates a damping force for relative movement of a corresponding sprung portion and a corresponding unsprung portion so as to change the magnitude thereof; and a controller that includes a reference damping force determining unit determining a reference damping force, which serves as a reference of the damping force generated from each of the plurality of shock absorbers, on the basis of a predetermined control rule, a correction value determining unit determining a correction value from the reference damping force for only the shock absorber corresponding to the sprung portion in which (i) the direction of actual sprung movement as actual movement in the vertical direction and (ii) the direction of vehicle body behavior-corresponding sprung movement as movement in the vertical direction when the behavior of a vehicle body based on a vehicle body behavior component as a component of vehicle body behavior is assumed are parallel to each other out of the plurality of shock absorbers so as to suppress the vehicle body behavior component, and a target damping force determining unit determining a target damping force as a target of the damping force to be generated from each of the plurality of shock absorbers on the basis of the reference damping force and the correction values and that controls the damping force generated from each of the plurality of shock absorbers by controlling the damping force changing mechanism of each of the plurality of shock absorbers.

[0005] According to this aspect, control for suppressing any one of a heave, a roll, and a pitch which are vehicle body behavior components is carried out. For example, it is assumed that a force for suppressing the vehicle body behavior-corresponding sprung movement is generated to suppress the vehicle body behavior components. Then, when the direction of the vehicle body behavior-corresponding sprung movement and the

direction of the actual sprung movement are parallel to each other, the force for suppressing the vehicle body behavior-corresponding sprung movement suppresses the actual sprung movement. However, when the direction of the vehicle body behavior-corresponding sprung movement and the direction of the actual sprung movement are antiparallel to each other, the force for suppressing the vehicle body behavior-corresponding sprung movement promotes the actual sprung movement.

[0006] According to this aspect, the correction for suppressing any one of the heave, the roll, and the pitch is performed on the damping force of the shock absorber corresponding to the sprung portion in which the direction of the vehicle body behavior-corresponding sprung movement and the direction of the actual sprung movement are parallel to each other, and the correction for suppressing any one of the heave, the roll, and the pitch is not performed on the damping force of the shock absorber corresponding to the sprung portion in which the direction of the vehicle body behavior-corresponding sprung movement and the direction of the actual sprung movement are antiparallel to each other. As will be described in detail later, by not correcting the damping force of the shock absorber corresponding to the sprung portion in which the direction of the vehicle body behavior-corresponding sprung movement and the direction of the actual sprung movement are antiparallel to each other, it is possible to suppress any one of the heave, the roll, and the pitch and to suppress the other components of the vehicle body behavior, that is, to suppress the entire behavior of the vehicle body. Accordingly, according to the aspect, it is possible to suppress the behavior of a vehicle body with a relatively simple technique.

[0007] According to the aspect explained above, the controller may include an actual sprung speed acquiring unit that acquires an actual sprung speed as a speed of the sprung movement of the sprung portion corresponding to each of the plurality of vehicle wheels and a vehicle body behavior-corresponding sprung speed acquiring unit that acquires a vehicle body behavior-corresponding sprung speed as a speed of the vehicle body behavior-corresponding sprung movement, and wherein the correction value determining unit may be configured to determine that the direction of the actual sprung

movement and the direction of the vehicle body behavior-corresponding sprung movement of the sprung portion are parallel to each other when the direction of the actual sprung speed and the direction of the vehicle body behavior-corresponding sprung speed are parallel to each other and to determine the correction value.

5 **[0008]** According to the aspect explained above, the correction value determining unit determines the correction value so that the higher the vehicle body behavior-corresponding sprung speed becomes, the larger the magnitude of the correction value becomes.

10 **[0009]** According to this aspect, it is possible to effectively suppress the vehicle body behavior components by setting the correction value to an appropriate value.

15 **[0010]** According to the aspect explained above, the correction value determining unit may be configured to increase the reference damping force of each of the plurality of shock absorbers (i) when the direction of the vehicle body behavior-corresponding sprung movement of the corresponding sprung portion is upward and the sprung portion and the unsprung portion move in a direction in which both are spaced away from each other or when the direction of the vehicle body behavior-corresponding sprung movement is downward and the sprung portion and the unsprung portion move in a direction in which both get close to each other, and to decrease the reference damping force (ii) when the direction of the vehicle body behavior-corresponding sprung movement of the corresponding sprung portion is downward and the sprung portion and the unsprung portion move in a direction in which both are spaced away from each other or when the direction of the vehicle body behavior-corresponding sprung movement is upward and the sprung portion and the unsprung portion move in a direction in which both get close to each other.

25 **[0011]** The damping force generated from a shock absorber acts on the relative movement of the sprung portion and the unsprung portion. Accordingly, for example, even when the direction in which the sprung portion will move is upward, it is preferable that whether to increase or decrease the reference damping force differ depending on the direction of the relative movement of the sprung portion and the unsprung portion. In this

aspect, whether to increase or decrease the reference damping force is determined depending on the direction of the vehicle body behavior-corresponding sprung movement and the direction of the relative movement of the sprung portion and the unsprung portion.

[0012] According to the aspect explained above, the correction value determining unit may determine the correction value so as to suppress any one of a heave, a roll, and a pitch as the vehicle body behavior component.

[0013] According to this aspect, it is possible to suppress a variation in posture of the vehicle body.

[0014] According to the aspect explained above, the correction value determining unit may determine the correction value so as to suppress any one of a heave, a roll, and a pitch as the vehicle body behavior component, and the controller may include a plurality of the correction value determining units.

[0015] In this aspect, two or all of the heave correction, the roll correction, and the pitch correction are performed. That is, for example, the correction values for the reference damping force and the vehicle body behavior components may all be added. At the time of adding the correction values, the correction values may be weighted. According to this aspect, it is possible to effectively suppress two or more of the heave, the roll, and the pitch.

[0016] According to the aspect explained above, each of the plurality of shock absorbers may include a cylinder that includes a housing containing an operating liquid, a piston disposed in the housing so as to be slidable, and a rod of which one end is connected to the piston and the other end extends from the housing, that is disposed to connect the sprung portion and the unsprung portion of the vehicle, and that expands and contracts with the relative movement of the sprung portion and the unsprung portion and a damping force generator that generates a damping force for at least one of the expansion and the contraction of the cylinder by giving resistance to a flow of the operating liquid accompanied with at least one of the expansion and the contraction of the cylinder, that is configured to generate a damping force of a magnitude corresponding to the magnitude of a supplied current, and that has a function of the damping force changing mechanism.

[0017] Each of the “plurality of shock absorbers” generates a damping force differing depending on the current supplied to the damping force generator. That is, in the above-mentioned aspect, the correction value determining unit can be configured to determine the correction value for a reference supply current so as to correct the reference supply current which is a current supplied to the damping force generator based on the reference damping force. According to this configuration, the damping force can be easily corrected within a controllable range and the target damping force or a target damping coefficient can be prevented from being corrected into the controllable range after being determined.

[0018] According to the aspect explained above, the damping force generator may include (A) a valve body, (B) an impelling member impelling the valve body in one direction of a valve-opening direction and a valve-closing direction, and (C) a solenoid including a moving member and a coil generating an electromagnetic force for operating the moving member with a supply of a current and is configured to adjust a valve-opening pressure of the valve body by controlling the operation of the moving member, and wherein the controller is configured to control the damping force generated from each of the plurality of shock absorbers by controlling the current supplied to the coil so as to adjust the valve-opening pressure of the valve body.

[0019] The “damping force generator” in this aspect may have a structure in which the solenoid directly applies a force to the valve body so as to change the valve-opening pressure of the valve body or may have a structure in which a pressure difference between the front side and the rear side of the valve body is adjusted. In the aspect, due to the structure for adjusting the valve-opening pressure of the valve body, when the cylinder expands and contracts at a low speed, it is difficult to control the damping force and the controllable range of the damping force is limited. That is, the complex control described in JP 10-324129 A is not suitable for the aspect. Accordingly, in the aspect, the control of performing the correction for suppressing the vehicle body behavior component on the damping force of the shock absorber corresponding to the sprung portion in which the direction of the vehicle body behavior-corresponding sprung

movement and the direction of the actual sprung movement are parallel to each other is effective.

BRIEF DESCRIPTION OF THE DRAWINGS

5 [0020] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic diagram illustrating an example where a damping force based on a heave is corrected while a vehicle is running;

10 FIG. 2 is a schematic diagram illustrating an example where a damping force based on a roll is corrected while a vehicle is running;

FIG. 3 is a schematic diagram illustrating an example where a damping force based on a pitch is corrected while a vehicle is running;

15 FIG. 4 is a diagram schematically illustrating a vehicle suspension system as an example of a claimable invention;

FIG. 5 is a cross-sectional view illustrating a hydraulic shock absorber illustrated in FIG. 4;

FIG. 6 is a cross-sectional view illustrating a damping force generator of the hydraulic shock absorber illustrated in FIG. 5;

20 FIG. 7 is a graph illustrating damping characteristics of the damping force generator illustrated in FIG. 6;

FIG. 8 is a graph illustrating a relationship between a reference damping coefficient and a vehicle speed;

25 FIG. 9 is a flowchart illustrating an absorber control program that is executed by a controller illustrated in FIG. 4; and

FIG. 10 is a block diagram illustrating functional units of the controller illustrated in FIG. 4.

DETAILED DESCRIPTION OF EMBODIMENTS

[0021] Hereinafter, an example of a claimable invention will be described in detail as an embodiment of the claimable invention with reference to the accompanying drawings. The claimable invention may be embodied in the aspects described in the summary of the invention and various aspects obtained by modifying or improving the aspects on the basis of knowledge of one skilled in the art, in addition to the below-described example. Modification examples of the below-described example may be constructed using technical details described in the summary of the invention.

[0022] [A] FIG. 4 as a configuration diagram of a vehicle suspension system schematically illustrates a vehicle suspension system 10 that is an example of the claimable invention. The suspension system 10 includes four suspension units 12 of an independent suspension type to correspond to front, rear, right, and left vehicles wheels 14, respectively, and each of the suspension units 12 is disposed between a suspension lower arm supporting the corresponding vehicle wheel 14 and constituting a part of an unsprung portion and a mount portion disposed in a vehicle body and constituting a part of a sprung portion so as to connect both. Each suspension unit 12 includes a coil spring 16 as a suspension spring and a hydraulic shock absorber 20, which are disposed in parallel to each other between the lower arm and the mount portion. The vehicle wheel 14 and the suspension unit 12 are generic names, and may be referenced by FL, FR, RL, and RR as subscripts indicating the vehicle wheel positions to correspond to the front-left wheel, the front-right wheel, the rear-left wheel, and the rear-right wheel as illustrated in the drawings when it is necessary to clarify any of the four vehicle wheels 14.

[0023] As illustrated in FIG. 5, the hydraulic shock absorber 20 includes a cylinder 22 and a damping force generator 24 as principal elements. The cylinder 22 includes a housing 30, a piston 32 that is disposed to be movable in the vertical direction in the housing 30, and a rod 34 of which one end (lower end) is connected to the piston 32 and the other end (upper end) extends upward from the housing 30. The housing 30 is connected to the lower arm and the upper end of the rod 34 is connected to the mount portion. That is, the cylinder 22 expands when the sprung portion and the unsprung portion relatively move in a direction in which both are spaced away from each other

(hereinafter, may be referred to as “at the time of rebounding movement” or “at the time of rebounding”) and contracts when the sprung portion and the unsprung portion relatively move in a direction in which both get close to each other (hereinafter, may be referred to as “at the time of bounding movement” or “at the time of bounding”).

5 [0024] The housing 30 has a substantially dual structure and includes a bottomed main tube 40 and an outer tube 42 disposed on the outer circumference side thereof. The piston 32 is disposed in the main tube 40 so as to slide. The inside of the main tube 40 is partitioned into a rod-side chamber 44 and an anti-rod-side chamber 46 which are two liquid chambers by the piston 32. A buffer chamber (may be referred to as “reservoir”) 10 50 containing an operating liquid is defined and formed between the main tube 40 and the outer tube 42.

 [0025] In the housing 30, an intermediate tube 60 is disposed between the main tube 40 and the outer tube 42. An annular liquid passage 62 is defined and formed between the inner circumferential surface of the intermediate tube 60 and the outer 15 circumferential surface of the main tube 40. A partition member 64 for partitioning the bottom of the anti-rod-side chamber 46 is disposed on the bottom of the main tube 40, and a bottom liquid passage 66 is formed between the partition member 64 and the bottom wall of the main tube 40.

 [0026] In the upper part of the main tube 40, a flow hole 70 is disposed for flow 20 of the operating liquid between the liquid passage 62 and the rod-side chamber 44. In a part close to the lower end of the main tube 40, a bottom flow hole 72 is disposed for flow of the operating liquid between the buffer chamber 50 and the bottom liquid passage 66.

 [0027] As will be described in detail later, the damping force generator 24 has a function of allowing the operating liquid flowing out of the rod-side chamber 44 and 25 flowing into the buffer chamber 50 via the liquid passage 62 to pass and giving resistance to the flow of the operating liquid.

 [0028] In the shock absorber 20, the operating liquid flows into the rod-side chamber 44 of the cylinder 22 from the anti-rod-side chamber 46 via a check valve 80 disposed in the piston 32, as indicated by a solid arrow in FIG. 5, at the time of bounding

movement. Since the volume of the operating liquid flowing into the rod-side chamber 44 is larger than the volume increasing in the rod-side chamber 44 with the movement of the piston 32, the operating liquid flows from the rod-side chamber 44 to the buffer chamber 50 via the flow hole 70, the liquid passage 62, and the damping force generator 24.

5 At this time, a damping force for the contraction of the cylinder 22, that is, a damping force for the bounding movement, is generated by the resistance given to the flow of the operating liquid passing through the damping force generator 24.

[0029] On the other hand, at the time of rebounding movement, similarly to the bounding movement, the operating fluid flows from the rod-side chamber 44 of the cylinder 22 to the buffer chamber 50 via the flow hole 70, the liquid passage 62, and the damping force generator 24. At this time, a damping force for the expansion of the cylinder 22, that is, a damping force for the rebounding movement, is generated by the resistance given to the flow of the operating liquid passing through the damping force generator 24. As indicated by a dotted arrow in FIG. 5, the operating liquid flows into the anti-rod-side chamber 42 of the cylinder 22 from the buffer chamber 50 via the bottom flow hole 72, the bottom liquid passage 66, and a check valve 82 disposed in the partition member 64.

[0030] The configuration and the operation of the damping force generator 24 will be described below with reference to FIG. 6. The damping force generator 24 is known (for example, the damping force generator described in JP 2011-132995 A) and thus description thereof will be made in brief. The damping force generator 24 includes a main valve 90 as a valve body for giving resistance to the operating liquid passing therethrough and a solenoid 92 for adjusting the valve-opening pressure of the main valve 90 as principal elements.

25 [0031] The main valve 90 is impelled in a contact direction by a compression coil spring 94 as an impelling member. The main valve 90 is opened when a force acting due to a pressure difference between a liquid pressure of a high-pressure chamber 96 as a liquid chamber on the front side (the left side of the main valve 90 in FIG. 6) and a liquid pressure of a low-pressure chamber 98 as a liquid chamber on the rear side (the right side of the

main valve 90 in FIG. 6) is greater than the impelling force of the spring 94. That is, as indicated by a dotted arrow in FIG. 6, a flow of the operating liquid from the liquid passage 62 to the buffer chamber 50 is generated, and the main valve 90 gives resistance to the flow of the operating liquid. The main valve 90 is provided with an orifice 100 for giving
5 resistance to the flow of the operating liquid from the high-pressure chamber 96 to the low-pressure chamber 98. The operating liquid passing through the orifice 100 flows to the buffer chamber 50 as indicated by a solid arrow in FIG. 6.

[0032] The solenoid 92 is a poppet type solenoid valve and includes a valve-moving member 110 and a coil 112 generating an electromagnetic force for causing
10 the valve-moving member 110 to move by excitation. The valve-moving member 110 includes a poppet type valve head 114 and can open and close the low-pressure chamber 98 by causing the valve head 114 to contact a valve sheet 116 and to be separated therefrom. The valve-moving member 110 is impelled in a direction in which the valve head 114 is separated therefrom by the compression coil spring 118. On the other hand, with the
15 excitation of the coil 112, an impelling force in a direction in which the valve head 114 contacts the valve sheet acts on the valve-moving member 110.

[0033] The solenoid 92 can adjust the degree of opening of the low-pressure chamber 98, that is, the volume of the operating liquid flowing from the low-pressure chamber 98 to the buffer chamber 50, with the above-mentioned configuration. That is,
20 the solenoid 92 can adjust the valve-opening pressure of the main valve 90 by adjusting the liquid pressure of the low-pressure chamber 98. The valve-opening pressure of the main valve 90 depends on the magnitude of a current supplied to the coil 112 of the solenoid 92. The larger the current becomes, the smaller the degree of opening of the low-pressure chamber 98 becomes, the higher the liquid pressure of the low-pressure chamber 98 becomes, and the higher the valve-opening pressure of the main valve 90 becomes.
25

[0034] The damping force generator 24 having the above-mentioned configuration has damping characteristics illustrated in FIG. 7. When the relative movement speed V_{st} (hereinafter, may be referred to as "stroke speed") of the sprung portion and the unsprung portion is low, the main valve 90 is not opened and the damping

force F depends on the resistance of the flow of the operating liquid passing through the orifice 100 formed in the main valve 90. When the pressure difference between the high-pressure chamber 96 and the low-pressure chamber 98 increases and the main valve 90 is opened, the damping force F depends on the resistance of the flow of the operating liquid passing through the main valve 90. As described above, the larger the current supplied to the coil 112 becomes, the higher the valve-opening pressure of the main valve 90 becomes.

[0035] The damping force generator 24 generates a damping force so as to change the magnitude thereof within the hatched area of FIG. 7. The damping force generated from the damping force generator 24 increases with an increase in the supplied current. That is, the damping force generator 24 is configured to generate the damping force of a magnitude corresponding to the magnitude of the current by changing the resistance of the flow of the operating liquid passing therethrough depending on the magnitude of the current supplied thereto. That is, each shock absorber 20 includes a damping force changing mechanism changing the magnitude of the damping force and generates the damping force for the relative movement of the sprung portion and the unsprung portion so as to change the magnitude thereof.

[0036] The suspension system 10 controls the shock absorbers 20 through the use of a suspension electronic control unit 200 (hereinafter, may be referred to as "ECU 200") as a controller. The ECU 200 is constituted by a computer including a CPU, a ROM, and a RAM as a main element. The ECU 200 is connected to drive circuits 202 that are disposed to correspond to the damping force generators 24 of the shock absorbers 20 and that can adjust currents to the corresponding damping force generators 24. The drive circuits 202 are connected to a battery [BAT] 204 and currents are supplied to the damping force generators 24 of the shock absorbers 20 from the battery 204.

[0037] A vehicle is provided with a vehicle speed sensor [V] 210 detecting a vehicle running speed (hereinafter, may be referred to as "vehicle speed"), four sprung acceleration sensors [Gz] 212 detecting vertical acceleration of the corresponding sprung portions of the vehicle body corresponding to the vehicle wheels 14, and four stroke

sensors [St] 214 detecting strokes of the cylinders 22 of the shock absorbers 20 for the vehicle wheels 14, which are all connected to the computer of the ECU 200. The ECU 200 controls the shock absorbers on the basis of signals from the sensors. In addition, characters in [] are signs used to illustrate the sensors and the like in the drawings. The ROM of the computer of the ECU 200 stores programs relevant to the shock absorbers 20 and a variety of data.

[0038] [B] Control of Shock Absorber

i) Determination of Reference Supply Current

The control of the shock absorbers 20 is basically to suppress vibration occurring in the vehicle by generating a damping force corresponding to the vehicle speed V . Specifically, a supply current I is controlled so that the higher the vehicle speed V becomes, the higher the damping force F becomes, that is, the higher the valve-opening pressure of the main valve 90 becomes. Specifically, the RAM of the ECU 200 stores map data illustrated in FIG. 8, and a reference supply current I_e serving as a reference of the supply current to the damping force generator 24 is determined for the vehicle speed V detected by the vehicle speed sensor 210 with reference to the map data. That is, in the suspension system 10 according to this embodiment, the reference damping force for the stroke speed V_{st} at the corresponding time is determined by determining the reference supply current I_e .

[0039] ii) Determination of Correction Value Based on Vehicle Body Behavior

Components

In the suspension system 10 according to this embodiment, the reference supply current I_e is corrected to suppress a heave, a roll, and a pitch which are vehicle body behavior components. Specifically, a correction value from the reference supply current I_e in each shock absorber 20 is calculated for each of the heave, the roll, and the pitch, and the correction values are added to the reference supply current I_e to determine a target supply current I^* . Methods of determining a correction value ΔI_H based on a heave, a correction value ΔI_R based on a roll, and a correction value ΔI_P based on a pitch will be sequentially described below.

[0040] (a) Correction Value Based on Heave

In the suspension system 10 according to this embodiment, in order to suppress the heave as a vehicle body behavior component which is a component of the vehicle body behavior, the correction value from the reference damping force is determined for only the shock absorber in which (i) the direction of actual sprung movement that is actual movement in the vertical direction and (ii) the direction of heave-corresponding sprung movement that is the vehicle body behavior-corresponding sprung movement in the vertical direction when the vehicle body behavior based on a heave is assumed are parallel to each other in the corresponding sprung portion out of the four shock absorbers 20. In other words, the suspension system 10 according to this embodiment does not perform the correction based on a heave for the shock absorber in which the direction of the actual sprung movement and the direction of the heave-corresponding sprung movement are antiparallel to each other out of the four shock absorbers 20.

[0041] Specifically, the actual sprung speeds V_{z_FR} , V_{z_FL} , V_{z_RR} , and V_{z_RL} corresponding to the four shock absorbers 20 are estimated on the basis of the detection result of the four sprung acceleration sensors 212. Subsequently, a heave speed V_H of the vehicle body which is a vehicle body behavior-corresponding sprung speed is calculated using the following expression on the basis of the actual sprung speeds of the four locations.

$$V_H = \frac{l_r}{l_f + l_r} \left(\frac{v_{z_FR} + v_{z_FL}}{2} - \frac{v_{z_RR} + v_{z_RL}}{2} \right) + \frac{v_{z_RR} + v_{z_RL}}{2}$$

Here, l_f represents a distance between the axial line of the front wheels and the point of center of gravity, and l_r represents a distance between the axial line of the rear wheels and the point of center of gravity. The actual sprung speed V_z and the heave speed V_H are defined to be positive in the upward direction and are defined to be negative in the downward direction. For each shock absorber 20, it is determined whether the direction of the actual sprung movement and the direction of the heave-corresponding sprung movement are parallel to each other, depending on whether the sign of the actual sprung speed V_z and the sign of the heave speed V_H acquired as described above are equal to each

other.

[0042] In the shock absorber 20 in which the direction of the actual sprung movement and the direction of the heave-corresponding sprung movement are parallel to each other, when the reference supply current is corrected, it is determined whether to set
 5 the supply current to be greater or smaller than the reference supply current, depending on whether the shock absorber 20 performs bounding movement or rebounding movement. Specifically, when the heave speed V_H is upward and the rebounding movement is performed, the damping force increases, that is, the supply current increases, to suppress the heave. When the heave speed V_H is upward and the bounding movement is
 10 performed, the supply current decreases so as not to promote the heave. In addition, when the heave speed V_H is downward and the rebounding movement is performed, the supply current decreases so as not to promote the heave. In addition, when the heave speed V_H is downward and the bounding movement is performed, the supply current increases to suppress the heave. The higher the heave speed V_H becomes, the greater the
 15 heave correction value ΔI_H of each shock absorber 20 becomes in proportion thereto.

[0043] The heave correction value ΔI_H of each shock absorber 20 is calculated using the following expression so as to be determined as described above when the sign of the corresponding actual sprung speed V_z and the sign of the heave speed V_H are equal to each other.

$$20 \quad \Delta I_H = C_H \cdot \text{sgn}(V_{st}) \cdot V_H$$

Here, C_H represents a gain, $\text{sgn}(x)$ represents a signum function of reversing the sign of x , and V_{st} represents a stroke speed estimated from the detection result of the stroke sensor 214. The stroke speed V_{st} is defined to be positive on the expansion side and to be negative on the contraction side. When the sign of the actual sprung speed V_z and the
 25 sign of the heave speed V_H are not equal to each other, the heave correction value ΔI_H of the shock absorber 20 is 0.

[0044] (b). Correction Value Based on Roll

In the suspension system 10 according to this embodiment, the correction value ΔI_R based on a roll is determined using the same method as the correction value based on the

heave. That is, in the suspension system 10 according to this embodiment, the correction value ΔI_R from the reference supply current I_e is determined for only the shock absorber in which (i) the direction of actual sprung movement and (ii) the direction of roll-corresponding sprung movement that is movement in the vertical direction when the vehicle body behavior based on a roll is assumed are parallel to each other in the corresponding sprung portion out of the four shock absorbers 20.

[0045] Specifically, the roll speed V_R that is a vehicle body behavior-corresponding sprung speed of the sprung portion corresponding to each shock absorber 20 is calculated using the following expression on the basis of the actual sprung speeds of the four locations.

$$v_{R_FR} = \frac{1}{2} \left\{ \left(v_{z_FR} - \frac{v_{z_FR} + v_{z_FL}}{2} \right) \frac{2}{T_f} + \left(v_{z_RR} - \frac{v_{z_RR} + v_{z_RL}}{2} \right) \frac{2}{T_r} \right\} \frac{T_f}{2}$$

$$v_{R_FL} = -v_{R_FR}$$

$$v_{R_RR} = \frac{1}{2} \left\{ \left(v_{z_FR} - \frac{v_{z_FR} + v_{z_FL}}{2} \right) \frac{2}{T_f} + \left(v_{z_RR} - \frac{v_{z_RR} + v_{z_RL}}{2} \right) \frac{2}{T_r} \right\} \frac{T_r}{2}$$

$$v_{R_RL} = -v_{R_RR}$$

Here, T_f represents the tread on the front wheel side and T_r represents the tread on the rear wheel side.

[0046] For each shock absorber 20, it is determined whether the direction of the actual sprung movement and the direction of the roll-corresponding sprung movement are parallel to each other, depending on whether the actual sprung speed V_z and the roll speed V_R acquired as described above are equal to each other. The roll correction value ΔI_R of each shock absorber 20 is calculated using the following expression when the sign of the corresponding actual sprung speed V_z and the sign of the roll speed V_R are equal to each other.

$$\Delta I_R = C_R \cdot \text{sgn}(V_{st}) \cdot V_R$$

When the sign of the actual sprung speed V_z and the sign of the roll speed V_R are not equal to each other, the roll correction value ΔI_R of the shock absorber 20 is 0.

[0047] (c) Correction Value Based on Pitch

In the suspension system 10 according to this embodiment, the correction value ΔI_P based on a pitch is determined using the same method as the correction value based on the heave. That is, in the suspension system 10 according to this embodiment, the correction value ΔI_P from the reference supply current I_e is determined for only the shock absorber in which (i) the direction of actual sprung movement and (ii) the direction of pitch-corresponding sprung movement that is movement in the vertical direction when the vehicle body behavior based on a pitch is assumed are parallel to each other in the corresponding sprung portion out of the four shock absorbers 20.

[0048] Specifically, the pitch speed V_P that is a vehicle body behavior-corresponding sprung speed of the sprung portion corresponding to each shock absorber 20 is calculated using the following expression on the basis of the actual sprung speeds of the four locations.

$$v_{P_F} = \frac{v_{z_FR} + v_{z_FL}}{2} - v_H$$

$$v_{P_R} = \frac{v_{z_RR} + v_{z_RL}}{2} - v_H$$

[0049] For each shock absorber 20, it is determined whether the direction of the actual sprung movement and the direction of the pitch-corresponding sprung movement are parallel to each other, depending on whether the actual sprung speed V_z and the pitch speed V_P acquired as described above are equal to each other. The pitch correction value ΔI_P of each shock absorber 20 is calculated using the following expression when the sign of the corresponding actual sprung speed V_z and the sign of the pitch speed V_P are equal to each other.

$$\Delta I_P = C_R \cdot \text{sgn}(V_{st}) \cdot V_P$$

When the sign of the actual sprung speed V_z and the sign of the pitch speed V_P are not equal to each other, the pitch correction value ΔI_P of the shock absorber 20 is 0.

[0050] iii) Determination of Target Damping Coefficient

The target supply current I^* of each shock absorber 20 is determined using the following expression on the basis of the reference supply current I_e , the heave correction

value ΔI_H , the roll correction value ΔI_R , and the pitch correction value ΔI_P that are determined as described above.

$$I^* = I_e + \Delta I_H + \Delta I_R + \Delta I_P$$

The supply current to the damping force generator 24 is controlled so as to reach the target supply current I^* determined using this expression.

[0051] [C] Control Program

The control of the vehicle suspension system according to this embodiment is performed by causing the ECU 200 to execute an absorber control program, the flowchart of which is illustrated in FIG. 9, for each shock absorber 20. This program is repeatedly executed at short time intervals (for example, several μsec to several tens of μsec). The control will be described in brief below with reference to the flowchart.

[0052] According to the absorber control program, in step 1 (hereinafter, "step" is abbreviated to "S"), the vehicle speed V is acquired from the vehicle speed sensor 210, and the reference supply current I_e is determined on the basis of the vehicle speed V with reference to map data illustrated in FIG. 8.

[0053] Subsequently, in S2, the actual sprung speed V_z and the stroke speed V_{st} of the sprung portion corresponding to the shock absorber 20 to be controlled are estimated. The actual sprung speed V_z and the stroke speed V_{st} are estimated on the basis of the detection values of the sprung acceleration sensor 212 and the stroke sensor 214 at the time of previously executing the program and the detection values at the time of currently executing the program. Subsequently, in S3, the heave speed V_H , the roll speed V_R , and the pitch speed V_P which are vehicle body behavior-corresponding sprung speeds of the sprung portion corresponding to the shock absorber 20 to be controlled are acquired. The vehicle body behavior-corresponding sprung speeds are calculated using other programs (of which the flowcharts are not illustrated) based on the above-mentioned calculation expressions.

[0054] In S4 and the steps subsequent thereto, the correction value of the reference supply current is determined. First, in S4, it is determined whether the product of the actual sprung speed V_z and the heave speed V_H is equal to or greater than 0. When

the product of the actual sprung speed V_z and the heave speed V_H is equal to or greater than 0, it is determined that the signs of the actual sprung speed V_z and the heave speed V_H are equal to each other, that is, the direction of the actual sprung movement and the direction of the heave-corresponding sprung movement are parallel to each other. When
5 the product of the actual sprung speed V_z and the heave speed V_H is equal to or greater than 0, the heave correction value ΔI_H is determined on the basis of the above-mentioned calculation expression in S5. On the other hand, when the product of the actual sprung speed V_z and the heave speed V_H is less than 0, the direction of the actual sprung movement and the direction of the heave-corresponding sprung movement are antiparallel
10 to each other and thus the heave correction value ΔI_H is set to 0 in S6 so as not to perform the correction based on the heave.

[0055] Subsequently, in S7 to S9, the roll correction value ΔI_R is determined by performing the same process as the process of determining the heave correction value in S4 to S6, and the pitch correction value ΔI_P is determined in S10 to S12.

15 [0056] In S13, the heave correction value ΔI_H , the roll correction value ΔI_R , and the pitch correction value ΔI_P that are determined as described above are added to the reference supply current I_e to determine the target supply current I^* . Subsequently, in S14, the target supply current I^* to the damping force generator 24 is determined on the basis of the target supply current I^* and the current is supplied. In this way, one-turn execution of
20 the absorber control program ends.

[0057] [D] Functional Configuration of Controller

It can be considered that the ECU 200 performing the above-mentioned control includes various functional units performing the above-mentioned various processes. As illustrated in FIG. 10, the ECU 200 includes (I) a reference damping force determining unit
25 250 that determines a reference damping force (reference supply current) serving as a reference of the damping forces generated from four shock absorbers 20 on the basis of a predetermined control rule, (II) correction value determining units 252, 254, and 256 that determine the correction value from the reference damping force for only the shock absorber in which the direction of the actual sprung movement of the corresponding sprung

portion and the direction of the vehicle body behavior-corresponding sprung movement are parallel to each other out of the four shock absorbers 20 so as to suppress a vehicle body behavior component as a component of the vehicle body behavior, and (III) a target damping force determining unit 258 that determines the target damping force (target supply current) serving as a target of the damping force generated from each of the four shock absorbers 20 on the basis of the reference damping force and the correction values.

[0058] The ECU 200 includes the three correction value determining units 252, 254, and 256. Specifically, the ECU 200 includes a heave correction value determining unit 252 that determines a correction value for suppressing the heave as the vehicle body behavior component, a roll correction value determining unit 254 that determines a correction value for suppressing the roll as the vehicle body behavior component, and a pitch correction value determining unit 256 that determines a correction value for suppressing the pitch as the vehicle body behavior component.

[0059] In addition, in the ECU 200 of the vehicle suspension system according to this embodiment, the reference damping force determining unit 250 is configured to include a section for performing the process of S1 of the absorber control program, the heave correction value determining unit 252 is configured to include a section for performing the processes of S4 to S6, the roll correction value determining unit 254 is configured to include a section for performing the processes of S7 to S9, the pitch correction value determining unit 256 is configured to include a section for performing the processes of S10 to S12, and the target damping force determining unit 258 is configured to include a section for performing the process of S13.

[0060] The ECU 200 includes an actual sprung speed acquiring unit 260 that acquires the actual sprung speed of the sprung portion corresponding to each of the four vehicle wheels 14 and a vehicle body behavior-corresponding sprung speed acquiring unit 262 that acquires the vehicle body behavior-corresponding sprung speed of the sprung portion corresponding to each of the four vehicle wheels. The three correction value determining units 252, 254, and 256 determines whether the direction of the actual sprung movement of the sprung portion and the direction of the vehicle body

behavior-corresponding sprung movement are parallel to each other on the basis of the actual sprung speed and the vehicle body behavior-corresponding sprung speed acquired by the actual sprung speed acquiring unit 260 and the vehicle body behavior-corresponding sprung speed acquiring unit 262. In addition, the actual sprung speed acquiring unit 260 is configured to include a section for performing the process of S2 in the absorber control program and the vehicle body behavior-corresponding sprung speed acquiring unit 262 is configured to include a section for performing the process of S3 in the programs (of which the flowcharts are not illustrated) calculating the heave speed V_H , the roll speed V_R , and the pitch speed V_P on the basis of the above-mentioned calculation expressions and the absorber control program.

[0061] [E] Vehicle Suspension System

The vehicle suspension system 10 according to this embodiment having the above-mentioned configuration can suppress the vehicle body behavior component to be corrected and can also suppress other vehicle body behavior components, by not adding the correction value for the corresponding vehicle body behavior component to the reference damping force for the damping force of the shock absorber corresponding to the sprung portion in which the direction of the actual sprung movement and the direction of the vehicle body behavior-corresponding sprung movement are antiparallel to each other. That is, it is possible to suppress the entire vehicle body behavior. Accordingly, the suspension system 10 according to this embodiment can suppress the vehicle body behavior with a relatively simple technique. The vehicle suspension system according to this embodiment is configured to perform all of the heave correction, the roll correction, and the pitch correction. According to the aspects of this embodiment, it is possible to effectively suppress each of the heave, the roll, and the pitch.

[0062] For example, a state is considered in which the front-left wheel passes through a concave part and the rear-right wheel passes through a convex part when a vehicle having four vehicle wheels on the right and left sides of the front and rear side runs as illustrated in FIG. 1. It is assumed that the vehicle body moves upward at the position of the center of gravity. That is, in the sprung portions corresponding to all the vehicle

wheels, the direction of the vehicle body behavior-corresponding sprung movement based on the heave is upward. On the other hand, regarding the direction of the actual sprung movement, the direction of the movement of the sprung portion corresponding to the front-left wheel passing through the concave part is downward and the direction of the movement of the sprung portion corresponding to the other three vehicle wheels are upward.

[0063] For example, in the example illustrated in FIG. 1, for the shock absorbers corresponding to the three vehicle wheels of the front-right wheel, the rear-right wheel, and the rear-left wheel in which the direction of the vehicle body behavior-corresponding sprung movement based on the heave and the direction of the actual sprung movement are parallel to each other, the correction values ΔF from the reference damping force F_e are determined and the damping forces generated from the shock absorbers are corrected. In this case, the moment around the center of gravity acting on the vehicle body has a direction indicated by a hollow arrow in FIG. 1. When a force for suppressing the heave is applied to the front-left wheel, the force promotes the moment acting on the vehicle body, that is, promotes the roll on the front wheels and the pitch on the left wheels. That is, in the vehicle suspension system according to this embodiment, it is possible to suppress the roll with the damping force generated from the shock absorber of the front-right wheel and to suppress the pitch with the damping force generated from the shock absorber of the rear-left wheel, by not performing the correction of suppressing the heave on the damping force generated from the shock absorber of the front-left wheel.

[0064] The same state as illustrated in FIG. 1 is also considered in which the front-left wheel passes through a concave part and the rear-right wheel passes through a convex part when a vehicle having four vehicle wheels on the right and left sides of the front and rear side runs. Regarding the direction of the vehicle body behavior-corresponding sprung movement based on the roll, the movement direction of the sprung portions corresponding to the front-right wheel and the rear-right wheel is upward and the movement direction of the sprung portions corresponding to the front-left wheel and the rear-left wheel is downward. On the other hand, regarding the direction of the

actual sprung movement, the movement direction of the sprung portion corresponding to the front-left wheel passing through the concave part is downward and the movement direction of the sprung portions corresponding to the other three vehicle wheels are upward.

5 **[0065]** In this case, as illustrated in FIG. 2, for the shock absorbers corresponding to the three vehicle wheels of the front-right wheel, the rear-right wheel, and the front-left wheel in which the direction of the vehicle body behavior-corresponding sprung movement based on the roll and the direction of the actual sprung movement are parallel to each other, the correction values ΔF from the reference damping force F_e are determined and the
10 damping forces generated from the shock absorbers are corrected. When a force for suppressing the roll is applied to the rear-left wheel, the force promotes the heave and the pitch on the left wheels. That is, in the vehicle suspension system according to this embodiment, it is possible to suppress the pitch with the damping force generated from the shock absorber of the front-left wheel and to suppress the heave with the damping forces
15 generated from the shock absorbers of the rear-right wheel and the front-right wheel, by not performing the correction of suppressing the roll on the damping force generated from the shock absorber of the front-left wheel.

[0066] The same state as illustrated in FIG. 1 is also considered in which the front-left wheel passes through a concave part and the rear-right wheel passes through a
20 convex part when a vehicle having four vehicle wheels on the right and left sides of the front and rear side runs. Regarding the direction of the vehicle body behavior-corresponding sprung movement based on the pitch, the movement direction of the sprung portions corresponding to the front-right wheel and the front-left wheel is downward and the movement direction of the sprung portions corresponding to the
25 rear-right wheel and the rear-left wheel is upward. On the other hand, regarding the direction of the actual sprung movement, the movement direction of the sprung portion corresponding to the front-left wheel passing through the concave part is downward and the movement direction of the sprung portions corresponding to the other three vehicle wheels are upward.

[0067] In this case, as illustrated in FIG. 3, for the shock absorbers corresponding to the three vehicle wheels of the rear-right wheel, the rear-left wheel, and the front-left wheel in which the direction of the vehicle body behavior-corresponding sprung movement based on the pitch and the direction of the actual sprung movement are parallel to each other, the correction values ΔF from the reference damping force F_e are determined and the damping forces generated from the shock absorbers are corrected. When a force for suppressing the pitch is applied to the front-right wheel, the force promotes the heave and the roll on the front wheels. That is, in the vehicle suspension system according to this embodiment, it is possible to suppress the roll with the damping force generated from the shock absorber of the front-left wheel and to suppress the heave with the damping forces generated from the shock absorbers of the rear-right wheel and the rear-left wheel, by not performing the correction of suppressing the pitch on the damping force generated from the shock absorber of the front-left wheel.

[0068] [F] Modification Example

The vehicle suspension system 10 according to the above-mentioned embodiment is configured to simply add the correction value based on the heave, the correction value based on the roll, and the correction value based on the pitch to each other, but the correction values may be weighted and then added to each other. In this configuration, each of the heave, the roll, and the pitch can be effectively suppressed, for example, by setting a weighting value depending on the vehicle and weighting any of the heave, the roll, and the pitch.

[0069] The vehicle suspension system 10 according to the above-mentioned embodiment is configured to perform all of the heave correction, the roll correction, and the pitch correction, but may be configured to perform two or only one of the corrections from the viewpoint of the simplification of the control.

[0070] In the above-mentioned embodiment, one of the plural correction value determining units 252, 254, and 256 may determine the correction value for suppressing the heave, roll, or pitch as the vehicle body behavior component. That is, only one of the correction value determining units 252, 254, and 256 may be provided.

[0071] The “reference damping force determining unit” in the embodiment may employ various control rules used in the past, such as a rule for determining the damping force depending on the running speed of the vehicle and a rule for determining the damping force depending on the acceleration or deceleration of the vehicle, as the
5 “predetermined control rule”. From the viewpoint of the simplification of the control, it is preferable that a relatively simple control rule be employed.

CLAIMS:

1. A vehicle suspension system comprising:

a plurality of shock absorbers that is disposed to correspond to a plurality of vehicle wheels, that each has a damping force changing mechanism changing the magnitude of a damping force, and that generates a damping force for relative movement of a corresponding sprung portion and a corresponding unsprung portion so as to change the magnitude thereof; and

a controller that includes a reference damping force determining unit determining a reference damping force, which serves as a reference of the damping force generated from each of the plurality of shock absorbers, on the basis of a predetermined control rule, a correction value determining unit determining a correction value from the reference damping force for only the shock absorber corresponding to the sprung portion in which (i) the direction of actual sprung movement as actual movement in the vertical direction and (ii) the direction of vehicle body behavior-corresponding sprung movement as movement in the vertical direction when the behavior of a vehicle body based on a vehicle body behavior component as a component of vehicle body behavior is assumed are parallel to each other out of the plurality of shock absorbers so as to suppress the vehicle body behavior component, and a target damping force determining unit determining a target damping force as a target of the damping force to be generated from each of the plurality of shock absorbers on the basis of the reference damping force and the correction values and that controls the damping force generated from each of the plurality of shock absorbers by controlling the damping force changing mechanism of each of the plurality of shock absorbers.

2. The vehicle suspension system according to claim 1, wherein the correction value determining unit determines the correction value so as to suppress any one of a heave, a roll, and a pitch as the vehicle body behavior component.

3. The vehicle suspension system according to claim 1, wherein the correction value determining unit determines the correction value so as to suppress any one of a heave, a roll, and a pitch as the vehicle body behavior component, and

wherein the controller includes a plurality of the correction value determining units.

4. The vehicle suspension system according to any one of claims 1 to 3, wherein the controller includes an actual sprung speed acquiring unit that acquires an actual sprung speed as a speed of the sprung movement of the sprung portion corresponding to each of the plurality of vehicle wheels and a vehicle body behavior-corresponding sprung speed acquiring unit that acquires a vehicle body behavior-corresponding sprung speed as a speed of the vehicle body behavior-corresponding sprung movement, and

wherein the correction value determining unit is configured to determine that the direction of the actual sprung movement and the direction of the vehicle body behavior-corresponding sprung movement of the sprung portion are parallel to each other when the direction of the actual sprung speed and the direction of the vehicle body behavior-corresponding sprung speed are parallel to each other and to determine the correction value.

5. The vehicle suspension system according to claim 4, wherein the correction value determining unit determines the correction value so that the higher the vehicle body behavior-corresponding sprung speed becomes, the larger the magnitude of the correction value becomes.

6. The vehicle suspension system according to any one of claims 1 to 5, wherein the correction value determining unit is configured to increase the reference damping force of each of the plurality of shock absorbers (i) when the direction of the vehicle body behavior-corresponding sprung movement of the corresponding sprung portion is upward and the sprung portion and the unsprung portion move in a direction in which both are spaced away from each other or when the direction of the vehicle body

behavior-corresponding sprung movement is downward and the sprung portion and the unsprung portion move in a direction in which both get close to each other, and to decrease the reference damping force (ii) when the direction of the vehicle body behavior-corresponding sprung movement of the corresponding sprung portion is downward and the sprung portion and the unsprung portion move in a direction in which both are spaced away from each other or when the direction of the vehicle body behavior-corresponding sprung movement is upward and the sprung portion and the unsprung portion move in a direction in which both get close to each other.

7. The vehicle suspension system according to any one of claims 1 to 6, wherein each of the plurality of shock absorbers includes a cylinder that includes a housing containing an operating liquid, a piston disposed in the housing so as to be slidable, and a rod of which one end is connected to the piston and the other end extends from the housing, that is disposed to connect the sprung portion and the unsprung portion of the vehicle, and that expands and contracts with the relative movement of the sprung portion and the unsprung portion and a damping force generator that generates a damping force for at least one of the expansion and the contraction of the cylinder by giving resistance to a flow of the operating liquid accompanied with at least one of the expansion and the contraction of the cylinder, that is configured to generate a damping force of a magnitude corresponding to the magnitude of a supplied current, and that has a function of the damping force changing mechanism.

8. The vehicle suspension system according to claim 7, wherein the damping force generator includes (A) a valve body, (B) an impelling member impelling the valve body in one direction of a valve-opening direction and a valve-closing direction, and (C) a solenoid including a moving member and a coil generating an electromagnetic force for operating the moving member with a supply of a current and is configured to adjust a valve-opening pressure of the valve body by controlling the operation of the moving member, and wherein the controller is configured to control the

damping force generated from each of the plurality of shock absorbers by controlling the current supplied to the coil so as to adjust the valve-opening pressure of the valve body.

FIG. 1

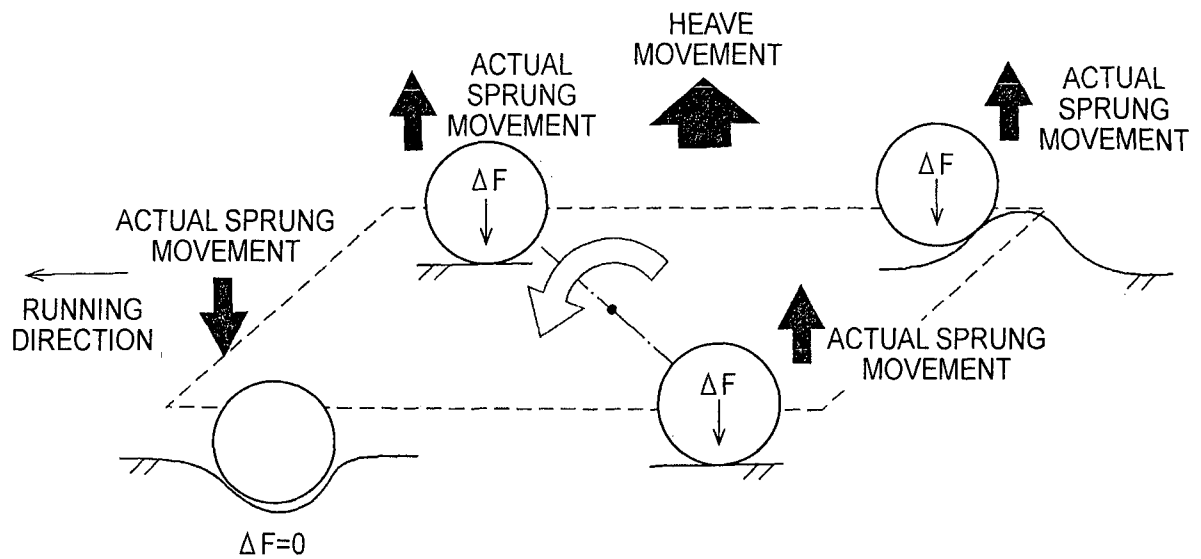


FIG. 2

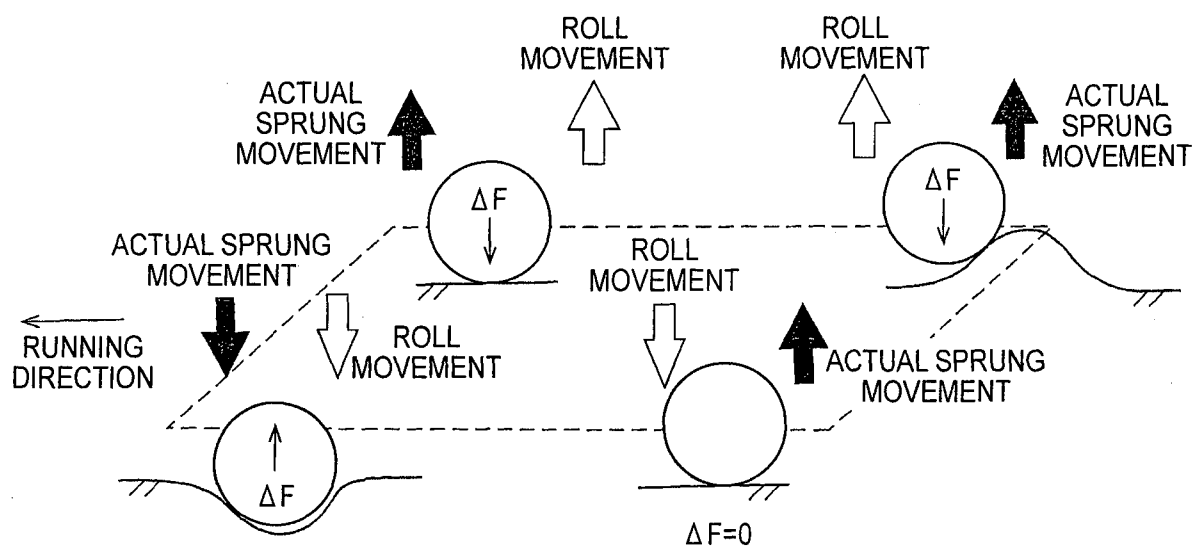


FIG. 3

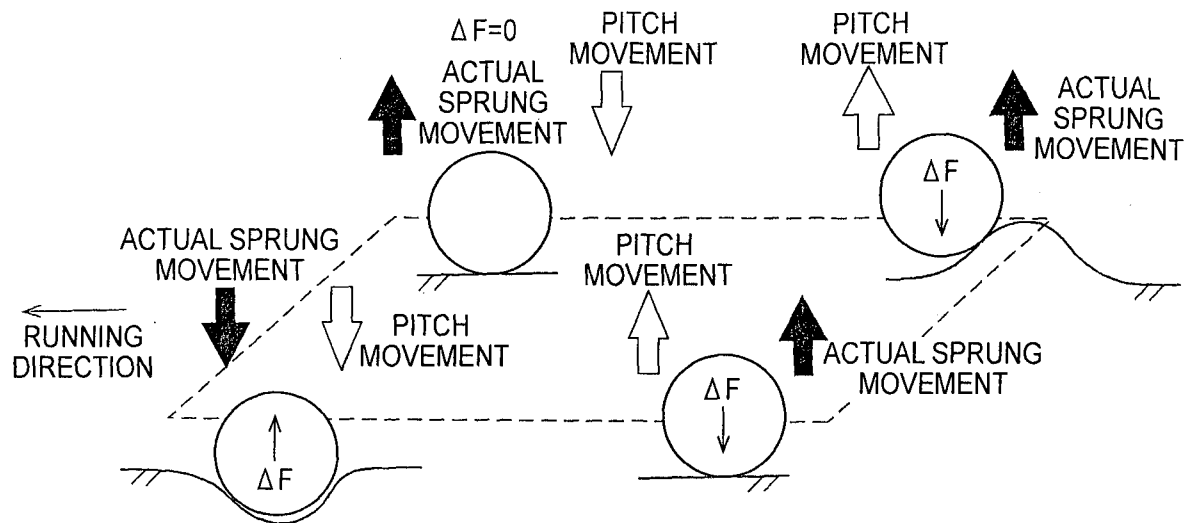


FIG. 4

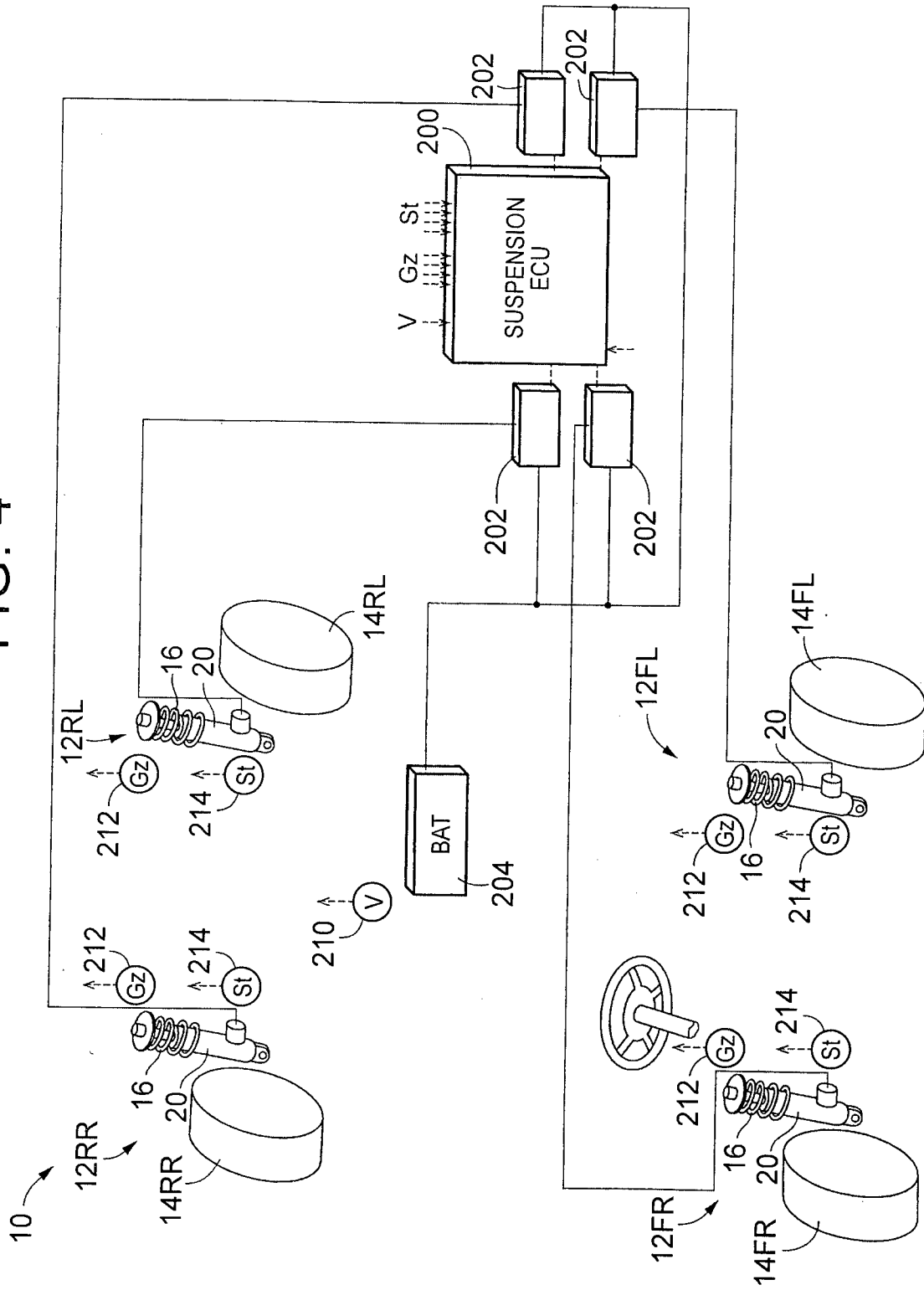


FIG. 5

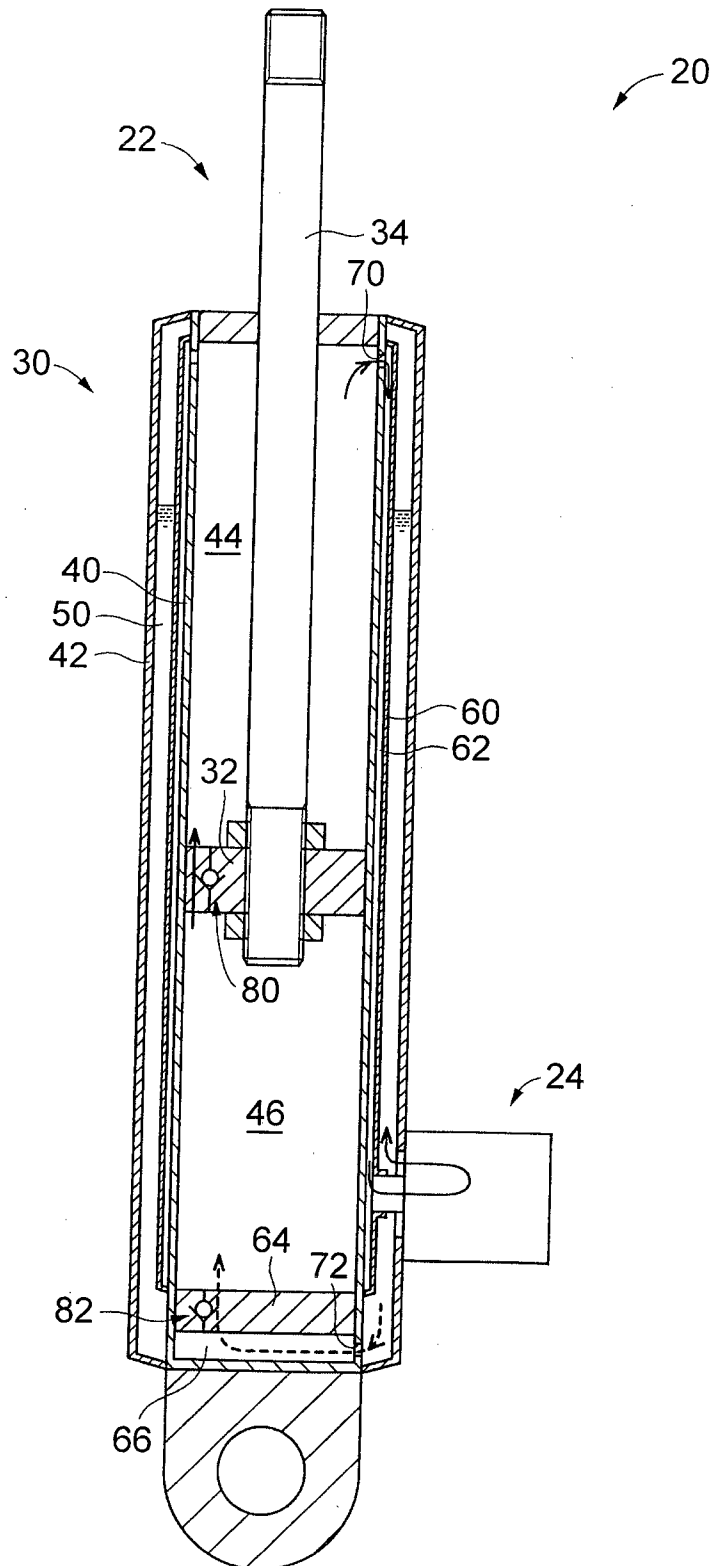


FIG. 6

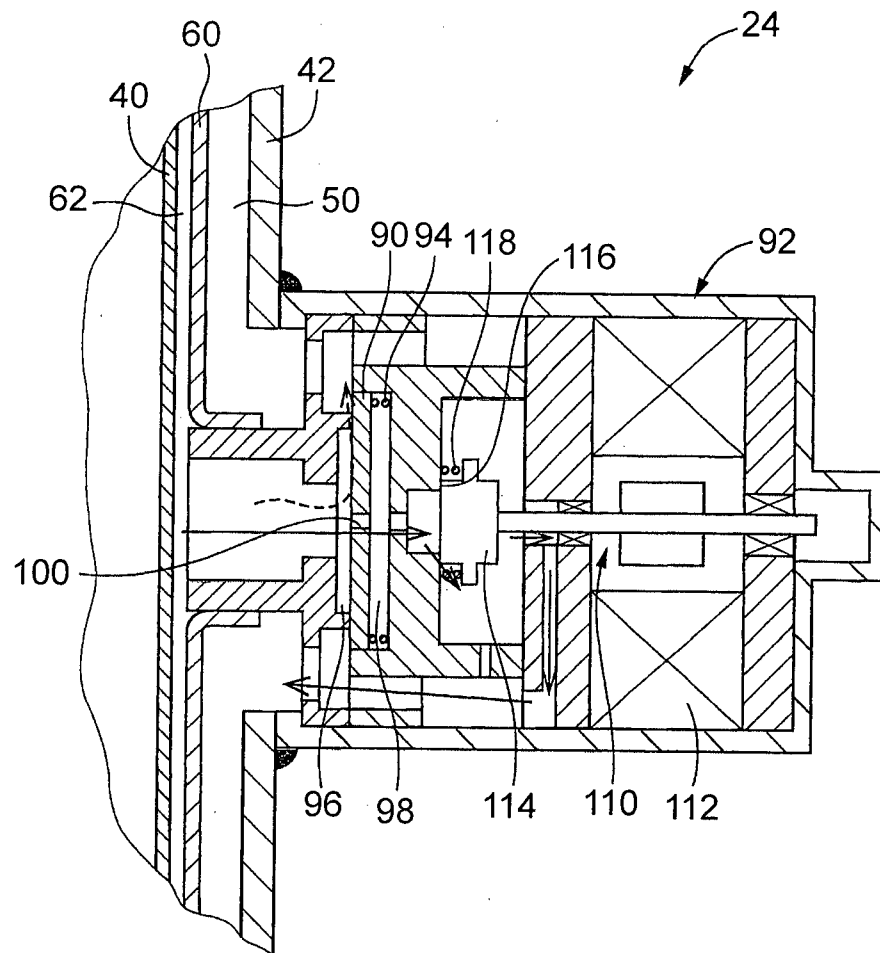


FIG. 7

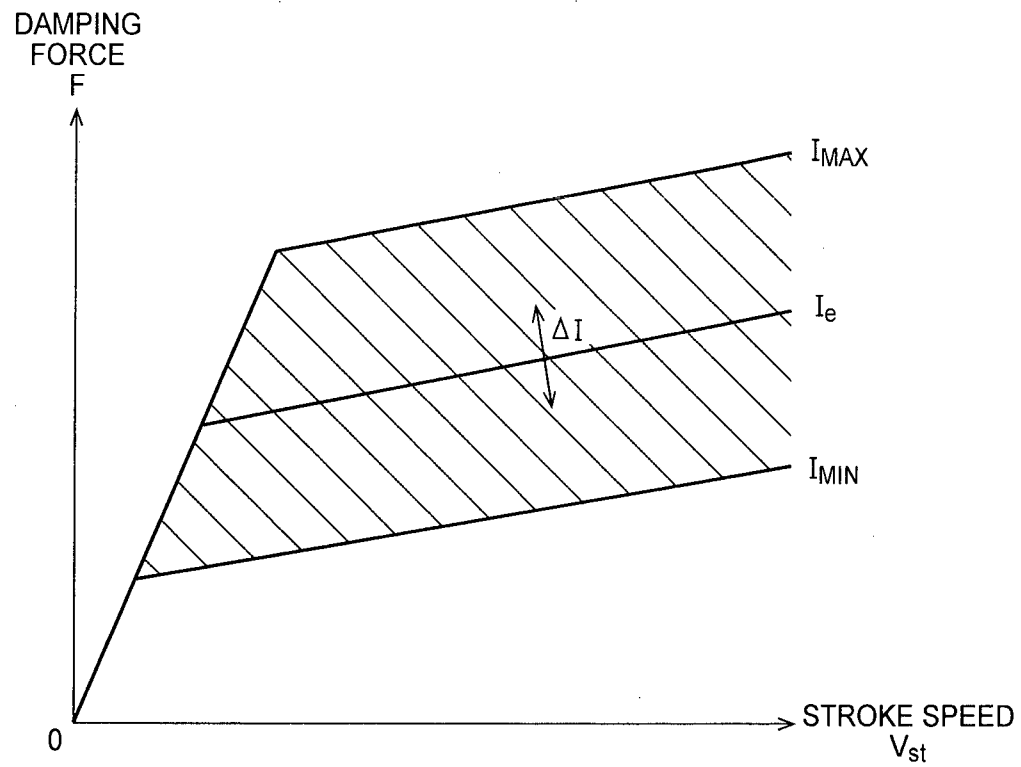


FIG. 8

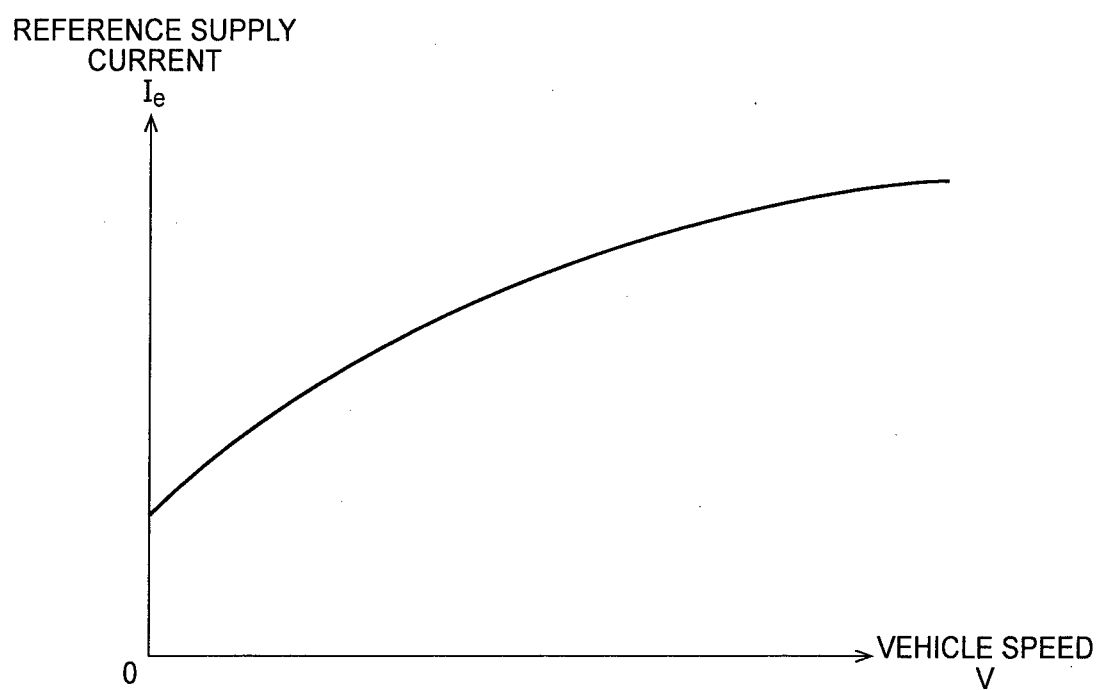


FIG. 9

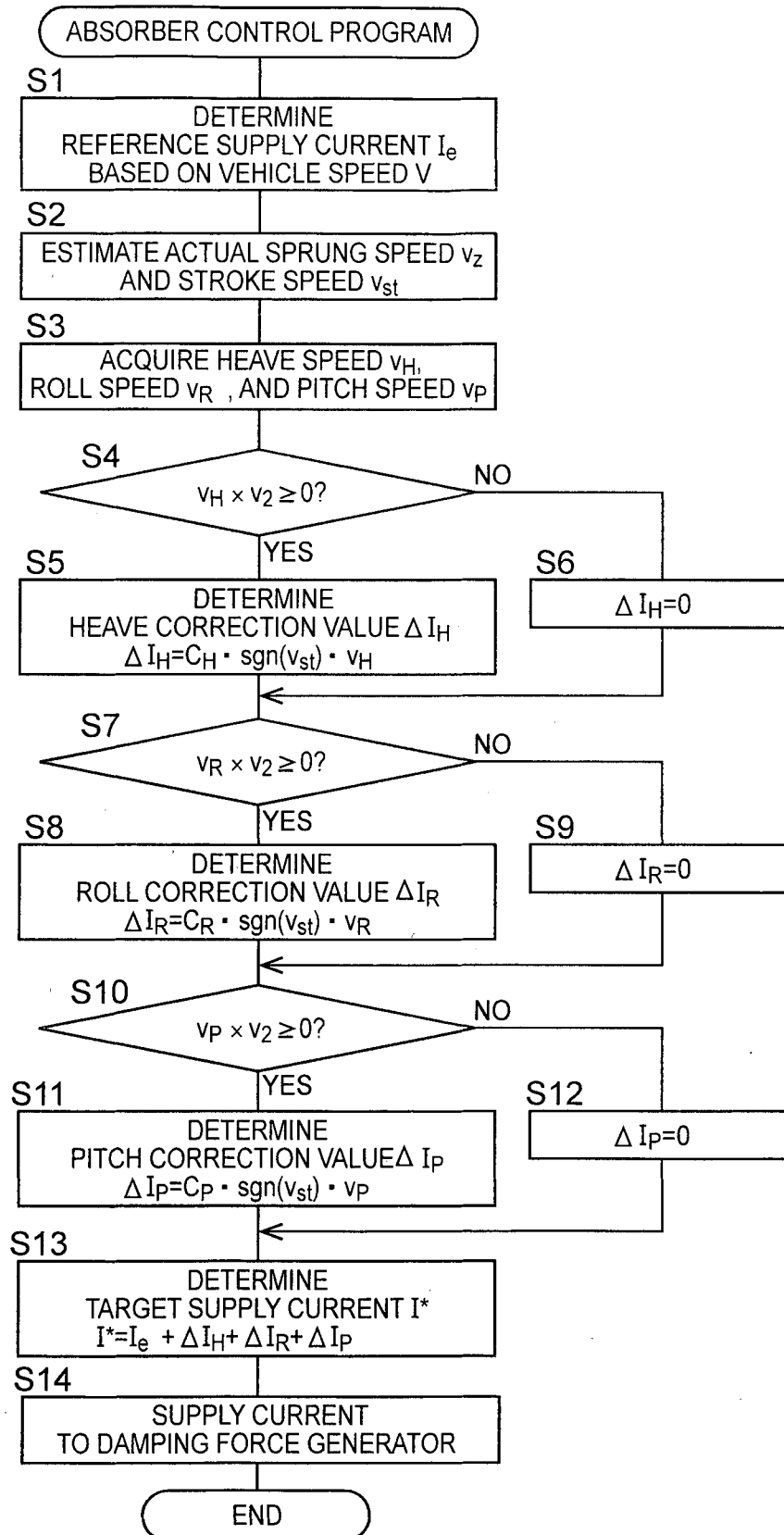
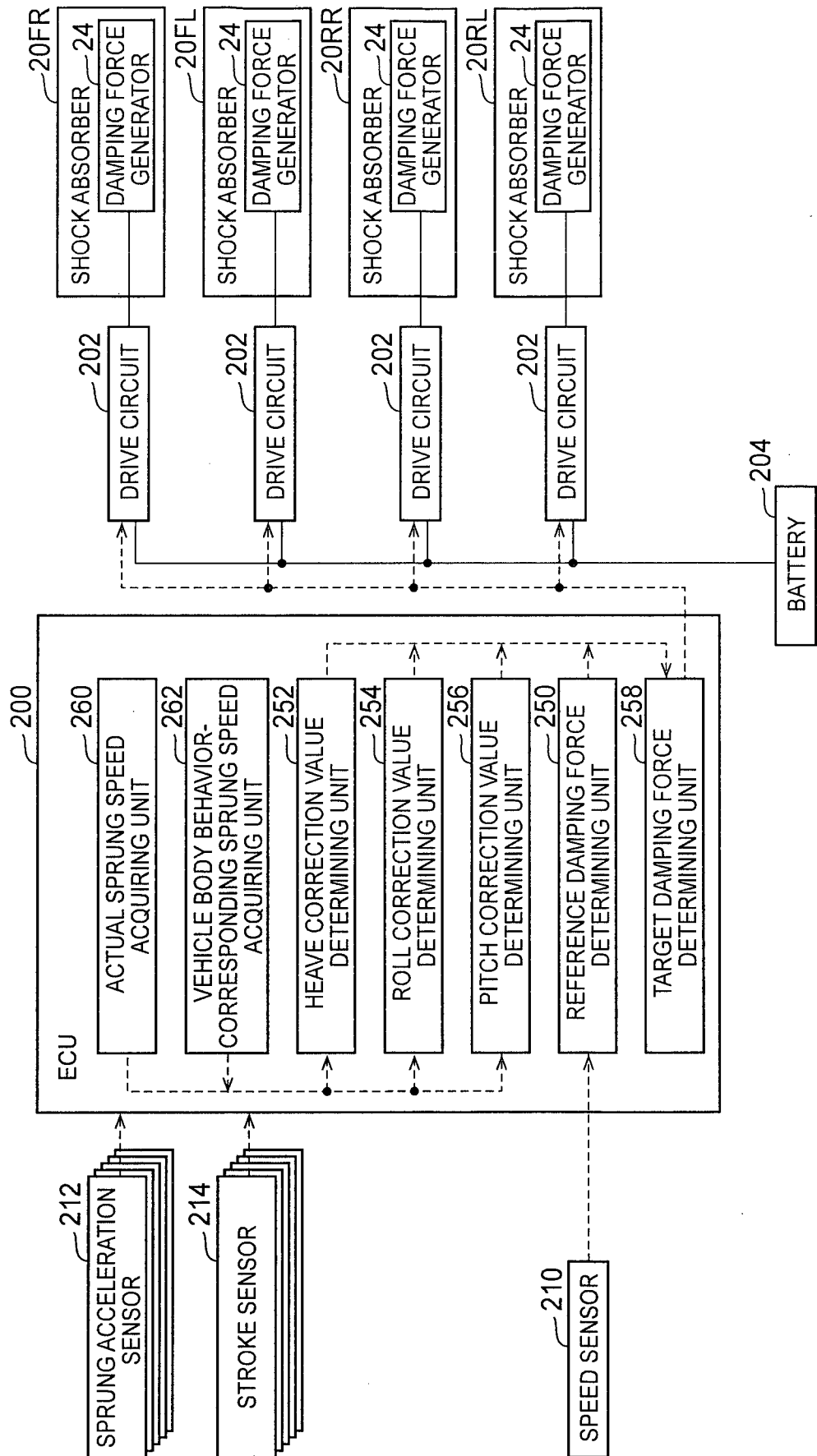


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/002558

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60G17/016
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)
B60G

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.
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A	US 2011/147147 A1 (MURAKAMI HIROSHI [JP]) 23 June 2011 (2011-06-23) figures -----	7,8
A	GB 2 281 722 A (UNISIA JECS CORP [JP]) 15 March 1995 (1995-03-15) page 12, line 10 - line 22; figures 1-3 -----	1-8
A	EP 0 426 340 A1 (GEN MOTORS CORP [US]) 8 May 1991 (1991-05-08) column 9, line 51 - column 10, line 2; figure 1 ----- -/-	1-8

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

11 March 2015

Date of mailing of the international search report

20/03/2015

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INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2014/002558

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No

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