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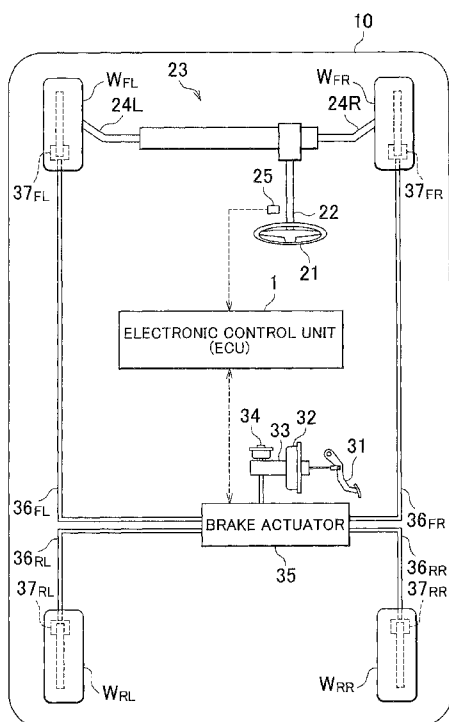
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[Continued on next page]

(54) Title: VEHICLE BEHAVIOR CONTROL DEVICE AND VEHICLE BEHAVIOR CONTROL METHOD

FIG. 1



(57) Abstract: A vehicle behavior control device executes vehicle behavior stabilizing control in which a braking control amount is generated at least one of front and rear turning outer wheels (WFL, WRL, WFR, WRR) to stabilize a behavior of a vehicle (10). In addition, when a condition for generating the braking control amounts at the front and rear turning outer wheels (WFL, WRL, WFR, WRR) is satisfied while the vehicle behavior stabilizing control is being executed, the vehicle behavior control device applies preliminary brake pressure to at least one of front and rear turning inner wheels (WFL, WRL, WFR, WRR).



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VEHICLE BEHAVIOR CONTROL DEVICE AND VEHICLE BEHAVIOR CONTROL METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a vehicle behavior control device and a vehicle behavior control method that stabilize the behavior of a vehicle.

2. Description of Related Art

[0002] A vehicle body shifts into turning through steering operation, the suspensions of turning outer wheels contract and the vehicle body starts roll motion. Generally, when countersteering is performed, a roll amount (roll moment) tends to increase at the time of the second or following steering operation as compared with at the time of the first steering operation from a steering center. For example, when the second steering is performed as countersteering, force in a returning direction (that is, extending direction) acts on the suspensions contracted through the first steering operation. In addition, the direction of a lateral acceleration quickly changes into an opposite direction. Thus, roll motion resulting from the first steering operation changes to opposite roll motion at a stroke through the second steering operation, and the roll moment increases. Thus, the roll amount increases at the time of the second or following steering operation as compared with at the time of the first steering operation. In addition, yaw motion also changes opposite yaw motion at a stroke in response to the second steering operation. Thus, yaw moment that is larger at the time of the second steering operation than at the time of the first steering operation acts on the vehicle body.

[0003] In an existing art, there is known the following vehicle behavior control device. In the vehicle behavior control device, when yaw moment is excessively large

in the second or following steering operation, opposite yaw moment is caused to act on the vehicle body to reduce the yaw moment. By so doing, the behavior of a vehicle is continuously maintained in a stable state while an excessive roll amount is suppressed. The vehicle behavior control device controls a brake actuator to apply braking force to at least one of turning outer wheels. The opposite yaw moment is generated by this braking force. At the time of applying braking force, the vehicle behavior control device preliminary applies brake fluid pressure (hereinafter, referred to as "preliminary brake pressure") to at least one of front and rear wheels that will be new turning outer wheels through opposite steering operation. The wheels that will be the new turning outer wheels indicate turning inner wheels before opposite steering operation. In addition, the wheels that will be the new turning outer wheels are also referred to as current turning inner wheels. Owing to the preliminary brake pressure, when the current turning inner wheels become turning outer wheels, required braking force may be applied to the new turning outer wheels with a high response. The preliminary brake pressure is generated by controlling the brake actuator. Hereinafter, control for applying the preliminary brake pressure is termed "preliminary brake pressure control".

[0004] For example, Japanese Patent Application Publication No. 2008-254724 (JP 2008-254724 A) and Japanese Patent Application Publication No. 11-227586 (JP 11-227586 A) respectively describe vehicle behavior control devices as described above. The vehicle behavior control device of JP 2008-254724 A executes control for suppressing over-steering by generating braking force at at least one of the turning outer wheels. When steering operation in a direction opposite to a turning direction has been detected during the suppressing control, preliminary brake pressure is applied to at least one of the wheels (current turning inner wheels) that will be the new turning outer wheels through the steering operation. In addition, the vehicle behavior control device of JP 11-227586 A executes vehicle horizontal behavior control by automatically braking at least one behavior control wheel. In the vehicle horizontal behavior control, the next at least one behavior control wheel is predicted on the basis of a combination of at least one current behavior control wheel and a variation tendency of a yaw rate deviation. Only

the next at least one behavior control wheel is set as a preliminary pressure control target wheel to which preliminary brake pressure is applied.

[0005] Preliminary brake pressure control may be carried out on the basis of an actual vehicle behavior or detected driver's countersteering. In such a mode as well, a certain effect may be obtained through preliminary brake pressure control. However, for example, in a situation that sudden countersteering is performed, output of preliminary brake pressure control may be too late or may be insufficient. As a result, a sufficient effect may not be obtained.

[0006] In addition, preliminary brake pressure control based on an actual vehicle behavior or detected driver's countersteering, a threshold may be set to ensure a response. However, in this case, it may lead to unnecessary operation through erroneous determination as to an actual vehicle behavior, or the like.

SUMMARY OF THE INVENTION

[0007] The invention provides a vehicle behavior control device and a vehicle behavior control method that apply preliminary brake pressure with a high response when quick output of preliminary brake pressure is required as well.

[0008] A first aspect of the invention relates to a vehicle behavior control device. The vehicle behavior control device includes: a behavior stabilizing control unit and a preliminary brake pressure applying unit. The behavior stabilizing control unit executes vehicle behavior stabilizing control in which a braking control amount is generated at at least one of front and rear turning outer wheels to stabilize a behavior of a vehicle. When a condition for generating the braking control amounts at the front and rear turning outer wheels is satisfied while the vehicle behavior stabilizing control is being executed, the preliminary brake pressure applying unit applies preliminary brake pressure to at least one of front and rear turning inner wheels.

[0009] In the first aspect of the invention, the preliminary brake pressure applying unit may detect steering operation in a direction opposite to a current turning direction of the vehicle while the vehicle behavior stabilizing control is being executed,

and may apply the preliminary brake pressure when the steering operation in the opposite direction has been detected.

[0010] In the first aspect of the invention, the preliminary brake pressure applying unit may apply the preliminary brake pressure to the front turning inner wheel when the vehicle behavior stabilizing control is over-steering suppressing control.

[0011] A second aspect of the invention relates to a vehicle behavior control method. The vehicle behavior control method includes: executing vehicle behavior stabilizing control in which a braking control amount is generated at at least one of front and rear turning outer wheels to stabilize a behavior of a vehicle; and, when a condition for generating the braking control amounts at the front and rear turning outer wheels is satisfied while the vehicle behavior stabilizing control is being executed, applying preliminary brake pressure to at least one of front and rear turning inner wheels.

[0012] According to the first and second aspects of the invention, preliminary brake pressure control is executed before the behavior of the vehicle resulting from countersteering is detected. Therefore, the preliminary brake pressure is applied before the turning direction of the vehicle body is inverted through driver's countersteering. Thus, according to the first and second aspects, when the turning direction of the vehicle body is inverted and vehicle behavior stabilizing control is executed, it is possible to generate the braking control amount for vehicle behavior stabilizing control with a high response at at least one new turning outer wheel to which the preliminary brake pressure is being applied. Particularly, the vehicle behavior control device is able to quickly output the preliminary brake pressure when quick output of the preliminary brake pressure is required as well, for example, when sudden countersteering is performed. By extension, it is possible to output the braking control amount for vehicle behavior stabilizing control with a high response after the turning direction is inverted. Thus, the vehicle behavior control device is able to improve the control performance of vehicle behavior stabilizing control.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] 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 view that shows an example of a vehicle to which a vehicle behavior control device according to an embodiment of the invention is applied;

FIG. 2 is a view that shows an example of a brake actuator;

FIG. 3 is a flow chart that illustrates major flow of anticipated preliminary brake pressure control executed by the vehicle behavior control device according to the embodiment;

FIG. 4 is a flow chart that illustrates preliminary brake pressure control executed by the vehicle behavior control device according to the embodiment; and

FIG. 5 is a flow chart that illustrates processes subsequent to the flow chart of FIG. 4.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] Hereinafter, an embodiment of a vehicle behavior control device according to the aspect of the invention will be described in detail with reference to the accompanying drawings. Note that the aspect of the invention is not limited by the embodiment.

[0015] The embodiment of the vehicle behavior control device according to the aspect of the invention will be described with reference to FIG. 1 to FIG. 5.

[0016] In the present embodiment, an electronic control unit (ECU) 1 shown in FIG. 1 has the vehicle behavior control device according to the aspect of the invention as one of functions.

[0017] First, an example of a vehicle 10 to which the vehicle behavior control device is applied is shown in FIG. 1.

[0018] The vehicle 10 is equipped with a steering system that turns steered wheels W_{FL} and W_{FR} through driver's steering operation. The steering system includes a steering wheel 21, a steering shaft 22, a steering torque transmission device 23, tie rods

24L and 24R and a steering operation amount detecting device 25. The steering wheel 21 is operated by the driver. The steering shaft 22 is coupled to the steering wheel 21. The steering torque transmission device 23 transmits the steering torque of the steering shaft 22 toward the left and right steered wheels W_{FL} and W_{FR} . The tie rods 24L and 24R respectively couple both ends of the steering torque transmission device 23 to the steered wheels W_{FL} and W_{FR} . The steering operation amount detecting device 25 detects the driver's steering operation amount of the steering wheel 21. The steering torque transmission device 23 is a so-called rack-and-pinion mechanism.

[0019] The steering operation amount is, for example, a steering angle δ . The steering operation amount detecting device 25 detects the steering angle δ from the rotation angle of the steering shaft 22, and transmits the detected signal to the electronic control unit 1. In the present embodiment, the steering angle δ is detected as a positive value when the steering wheel 21 is steered from a neutral position (steering center) in the counterclockwise direction (left-turn direction), and is detected as a negative value when the steering wheel 21 is steered from the steering center in the clockwise direction. The electronic control unit 1 computes a steering angular velocity ω_{str} on the basis of a variation in the steering angle δ with time ($\omega_{str} = d\delta/dt$). Thus, the steering angular velocity ω_{str} is a positive value when the steering wheel 21 is steered in the counterclockwise direction, and is a negative value when the steering wheel 21 is steered in the clockwise direction.

[0020] Note that, here, the steering system in which the steering wheel 21 and the steered wheels W_{FL} and W_{FR} are mechanically connected is illustrated. However, the steering system may be of a so-called steer-by-wire type having no mechanical connection therebetween.

[0021] In addition, the vehicle 10 includes a power source (not shown), such as an engine and a motor. The vehicle 10 transmits the power of the power source to drive wheels as driving force to run. Then, the vehicle 10 is equipped with a braking system that stops or decelerates the vehicle 10 while running. The braking system generates a target braking control amount (target wheel braking torque, target wheel braking force)

individually at each of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} . Here, the vehicle utilizes the force of brake fluid pressure to generate friction force between engagement elements to thereby apply the target braking control amounts to the respective wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} .

5 **[0022]** Initially, as shown in FIG. 1 and FIG. 2, the braking system includes a brake pedal 31, a brake booster 32, a master cylinder 33 and a reservoir tank 34. The brake pedal 31 is operated by the driver. The brake booster 32 boosts operation pressure (pedal depression force), input to the brake pedal 31 through brake operation, at a predetermined ratio. The master cylinder 33 converts the pedal depression force
10 boosted by the brake booster 32 to a brake fluid pressure (hereinafter, referred to as "master cylinder pressure") corresponding to the operation amount of the brake pedal 31. The reservoir tank 34 stores brake fluid. These brake pedal 31, brake booster 32, and the like, function as a fluid pressure generating device that generates a brake fluid pressure corresponding to the driver's operation amount of the brake pedal 31.

15 **[0023]** In addition, as shown in FIG. 1 and FIG. 2, the braking system includes a master cylinder pressure regulating device (hereinafter, referred to as "brake actuator") 35, fluid pressure lines 36_{FL} , 36_{FR} , 36_{RL} and 36_{RR} and braking devices 37_{FL} , 37_{FR} , 37_{RL} and 37_{RR} . The brake actuator 35 regulates the master cylinder pressure for each of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} . The brake fluid pressure (master cylinder pressure or
20 brake fluid pressure regulated from the master cylinder pressure) through the brake actuator 35 is supplied via a corresponding one of the fluid pressure lines 36_{FL} , 36_{FR} , 36_{RL} and 36_{RR} . Then, the braking devices 37_{FL} , 37_{FR} , 37_{RL} and 37_{RR} respectively generate braking control amounts (wheel braking torques, wheel braking forces) at the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} .

25 **[0024]** The braking devices 37_{FL} , 37_{FR} , 37_{RL} and 37_{RR} are friction brake devices, and each are, for example, formed of a disc rotor, a caliper, and the like. The braking devices 37_{FL} , 37_{FR} , 37_{RL} and 37_{RR} each apply friction force to a member that rotates integrally with a corresponding one of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} to thereby suppress the rotation of the corresponding one of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} for

braking operation. The braking devices 37_{FL}, 37_{FR}, 37_{RL} and 37_{RR} respectively generate braking control amounts corresponding to the master cylinder pressure or regulated brake fluid pressure, fed from the brake actuator 35. In the following description, the braking control amount generated from the master cylinder pressure is termed "master pressure
5 braking control amount". In addition, the braking control amount generated from the regulated brake fluid pressure obtained by pressurizing the master cylinder pressure is termed "pressurized braking control amount".

[0025] The brake actuator 35 according to the present embodiment is illustrated to include a first fluid pressure system and a second fluid pressure system. The first
10 fluid pressure system transfers brake fluid pressure to the right front wheel W_{FR} and the left rear wheel W_{RL}. The second fluid pressure system transfers brake fluid pressure to the left front wheel W_{FL} and the right rear wheel W_{RR}. That is, the brake actuator 35 has a structure having an X-pipe arrangement brake fluid pressure circuit. The brake actuator 35 is actuated in accordance with a control command from the electronic control
15 unit 1.

[0026] Here, two hydraulic pressure chambers (not shown) are provided inside the master cylinder 33. Then, the above master cylinder pressure is generated in each of the hydraulic pressure chambers. In the first fluid pressure system, the brake fluid pressure (master cylinder pressure) of one of the hydraulic pressure chambers of the
20 master cylinder 33 is supplied to the brake actuator 35 via a first fluid pressure line 38. The brake actuator 35 supplies the brake fluid pressure directly at the master cylinder pressure or the brake fluid pressure regulated from the master cylinder pressure to the braking device 37_{FR} of the right front wheel W_{FR} and the braking device 37_{RL} of the left rear wheel W_{RL}. On the other hand, in the second fluid pressure system, the brake fluid
25 pressure (master cylinder pressure) of the other one of the hydraulic pressure chambers is supplied to the brake actuator 35 via a second fluid pressure line 39. The brake actuator 35 supplies the brake fluid pressure directly at the master cylinder pressure or the brake fluid pressure regulated from the master cylinder pressure to the braking device 37_{FL} of the left front wheel W_{FL} and the braking device 37_{RR} of the right rear wheel W_{RR}.

[0027] A master cylinder pressure sensor 41 is provided at the brake actuator 35.

The master cylinder pressure sensor 41 detects the master cylinder pressure. The master cylinder pressure sensor 41 is arranged in any one of the first and second fluid pressure lines 38 and 39, and transmits a detected signal to the electronic control unit 1. Here, it is illustrated that the master cylinder pressure sensor 41 is provided in the first fluid pressure line 38.

[0028] In addition, the brake actuator 35 includes master cut valves 42 and 43

respectively in the first and second fluid pressure systems. Here, the master cut valve 42 is arranged downstream of the master cylinder pressure sensor 41. These master cut

valves 42 and 43 are so-called normally-open regulating electromagnetic valves, and are open when no current is supplied. The master cut valves 42 and 43 regulate a flow rate

of the brake fluid. In the present embodiment, the valve opening degrees of the master cut valves 42 and 43 are controlled with current supplied from the electronic control unit

1. The valve opening degree of each of the master cut valves 42 and 43 is controlled on the basis of a supplied current. By so doing, each of the master cut valves 42 and 43

regulates brake fluid pressure discharged from a corresponding one of pressure pumps 69 and 70 (described later), and releases the regulated brake fluid pressure to the master

cylinder 33. Note that a downstream side in this embodiment indicates a downstream side in a direction in which brake fluid flows at the time of pedal operation (that is,

direction toward the braking devices 37_{FL}, 37_{FR}, 37_{RL} and 37_{RR}).

[0029] In the brake actuator 35, the first fluid pressure line 38 is connected to a

coupling passage 44 via the master cut valve 42. On the other hand, the second fluid pressure line 39 is connected to a coupling passage 45 via the master cut valve 43. Then,

two branching passages 46 and 47 are connected to the coupling passage 44 of the first fluid pressure system, and are branched off from the coupling passage 44. Two

branching passages 48 and 49 are connected to the coupling passage 45 of the second fluid pressure system, and are branched off from the coupling passage 45. In the first

fluid pressure system, the branching passages 46 and 47 are respectively connected to the fluid pressure line 36_{FR} of the right front wheel W_{FR} and the fluid pressure line 36_{RL} of

the left rear wheel W_{RL} . On the other hand, in the second fluid pressure system, the branching passages 48 and 49 are respectively connected to the fluid pressure line 36_{RR} of the right rear wheel W_{RR} and the fluid pressure line 36_{FL} of the left front wheel W_{FL} .

[0030] In addition, a brake fluid pressure regulating device is arranged in each of the branching passages 46, 47, 48 and 49 for each of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} . Each brake fluid pressure regulating device is able to regulate the brake fluid pressure of a corresponding one of the braking devices 37_{FL}, 37_{FR}, 37_{RL} and 37_{RR}. Each of the brake fluid pressure regulating devices includes a retention valve 50, 51, 52 or 53, a fluid pressure drain passage 54, 55, 56 or 57 and a pressure reducing valve 58, 59, 60 or 61 that are prepared for a corresponding one of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} . Here, the retention valves 50, 51, 52 and 53 are respectively arranged in the branching passages 46, 47, 48 and 49. Furthermore, the fluid pressure drain passages 54, 55, 56 and 57 are respectively connected to the branching passages 46, 47, 48 and 49 downstream of these retention valves 50, 51, 52 and 53. That is, the fluid pressure drain passages 54, 55, 56 and 57 are respectively connected so as to be branched off from the branching passages 46, 47, 48 and 49. Then, the pressure reducing valves 58, 59, 60 and 61 are respectively arranged in the fluid pressure drain passages 54, 55, 56 and 57.

[0031] Each of the retention valves 50, 51, 52 and 53 is a so-called normally-open electromagnetic valve, and is open when no current is supplied. In the present embodiment, the retention valves 50, 51, 52 and 53 each are closed with current supplied from the electronic control unit 1. On the other hand, each of the pressure reducing valves 58, 59, 60 and 61 is a so-called normally-closed electromagnetic valve, and is closed when no current is supplied. In the present embodiment, the pressure reducing valves 58, 59, 60 and 61 each are opened with current supplied from the electronic control unit 1.

[0032] In addition, in the first fluid pressure system, a fluid pressure drain collecting passage 62 is prepared. The fluid pressure drain collecting passage 62 combines the fluid pressure drain passages 54 and 55 together. On the other hand, in the second fluid pressure system, a fluid pressure drain collecting passage 63 is prepared.

The fluid pressure drain collecting passage 63 combines the fluid pressure drain passages 56 and 57 together. The fluid pressure drain collecting passages 62 and 63 are respectively connected to auxiliary reservoirs 64 and 65.

[0033] Furthermore, in the first fluid pressure system, a pump passage 66 is
5 arranged. The pump passage 66 branches off from the branching point between the coupling passage 44 and each of the branching passages 46 and 47 and is connected to the fluid pressure drain collecting passage 62. Similarly, in the second fluid pressure system, a pump passage 67 is arranged. The pump passage 67 branches off from the branching point between the coupling passage 45 and each of the branching passages 48
10 and 49 and is connected to the fluid pressure drain collecting passage 63.

[0034] Pressure pumps (pressure devices) 69 and 70 are respectively arranged in the pump passages 66 and 67. The pressure pumps 69 and 70 are driven by an electric motor 68. The pressure pump 69 discharges brake fluid toward the branching point adjacent to the master cut valve 42. In addition, the pressure pump 69 supplies the
15 pressurized brake fluid pressure to the branching passages 46 and 47. On the other hand, the pressure pump 70 discharges brake fluid toward the branching point adjacent to the master cut valve 43. In addition, the pressure pump 70 supplies the pressurized brake fluid pressure to the branching passages 48 and 49. That is, the pressure pump 69 of the first fluid pressure system increases brake fluid pressure supplied to the braking devices
20 37_{FR} and 37_{RL}. By so doing, the pressure pump 69 of the first fluid pressure system increases braking force to be generated at the right front wheel W_{FR} and the left rear wheel W_{RL} . On the other hand, the pressure pump 70 of the second fluid pressure system increases brake fluid pressure supplied to the braking devices 37_{FL} and 37_{RR}. By
25 so doing, the pressure pump 70 of the second fluid pressure system increases braking force to be generated at the left front wheel W_{FL} and the right rear wheel W_{RR} . Note that the electric motor 68 is driven using electric power supplied from a battery (not shown). In addition, damper chambers 71 and 72 are respectively arranged in the pump passages 66 and 67. The damper chambers 71 and 72 each avoid pulsation of brake fluid discharged from a corresponding one of the pressure pumps 69 and 70.

[0035] In addition, suction passages 73 and 74 are arranged in the brake actuator 35. The suction passages 73 and 74 respectively branch off from the first and second fluid pressure lines 38 and 39, and are connected to the auxiliary reservoirs 64 and 65. Furthermore, reservoir cut check valves 75 and 76 are respectively arranged in the suction passages 73 and 74 adjacent to the auxiliary reservoirs 64 and 65.

[0036] The operation of the thus configured braking system according to the present embodiment is controlled by the electronic control unit 1 as described above. For example, anti-lock brake system (ABS) control, vehicle stability control (VSC), or the like, may be executed by the electronic control unit 1. Alternatively, the electronic control unit 1 sets the target braking control amount of a control target wheel on the basis of the driver's operation amount of the brake pedal 31 and a value required from the vehicle behavior control device (described later). When the master pressure braking control amount is shorter than the target braking control amount, the electronic control unit 1 obtains a target brake fluid pressure of the control target wheel, which compensates for the shortage. Then, the electronic control unit 1 controls the brake actuator 35 on the basis of the target brake fluid pressure to pressurize the master cylinder pressure. Thus, the pressurized braking control amount that satisfies the target braking control amount is generated at the braking device 37_{FL} (37_{FR}, 37_{RL} or 37_{RR}) of the control target wheel.

Vehicle Behavior Control Device

[0037] In addition, the electronic control unit 1 according to the present embodiment prepares the vehicle behavior control device as its one function as described above. The vehicle behavior control device executes vehicle behavior stabilizing control for stabilizing the behavior of the vehicle 10 while turning.

[0038] Specifically, the vehicle behavior control device controls the brake actuator 35 during turning, and generates a braking control amount (wheel braking torque, wheel braking force) at at least one of the front and rear turning outer wheels to thereby stabilize the behavior of the vehicle 10 while turning. For example, the vehicle behavior control device generates yaw moment, in a direction opposite to the direction of yaw moment acting on the vehicle body with turning, in the vehicle body through braking

control over the at least one of the turning outer wheels. By so doing, the vehicle behavior control device executes over-steering suppressing control (so-called spin control) over the vehicle 10 in turning. Thus, the vehicle behavior control device brings the vehicle body that indicates over-steering tendency close to neutral-steering. In the spin control, a target braking control amount FF_{out0} is generated at the front turning outer wheel. In addition, in the spin control, a target braking control amount FR_{out0} may be generated at the rear turning outer wheel. In this case, the target braking control amount FF_{out0} generated at the front turning outer wheel is set so as to be larger than the target braking control amount FR_{out0} generated at the rear turning outer wheel.

10 [0039] Braking control over the at least one of the turning outer wheels in the spin control is executed on the basis of the magnitude of roll moment and the magnitude of yaw moment that occur when the vehicle 10 turns through driver's steering operation. Here, the driver may perform the first steering operation from the steering center as a starting point and then perform the second steering operation that is subsequent to the first steering operation, that is in a direction opposite to the direction of the first steering operation and that exceeds the steering center. That is, the driver may perform countersteering in which the steering wheel 21 is steered leftward and rightward alternately two or more times successively with respect to the steering center. For example, the situation in which countersteering is performed is a situation in which the vehicle runs on a turning road having successive and alternate left and right turning directions, a situation in which the vehicle runs through a slalom, or the like. Then, when the countersteering is performed, in the vehicle 10, excessive roll moment and yaw moment may act on the vehicle body when the second or following steering operation is performed at the time of countersteering as compared with at the time of the first steering operation. Therefore, spin control may be executed when the driver performs the first steering operation from the steering center as a starting point; however, spin control is more likely to be executed when the second or following steering operation is performed at the time of countersteering. For example, the vehicle behavior control device executes control such that excessive roll moment and yaw moment do not act on the

vehicle body when steering operation that is in a direction opposite to the direction of the current steering operation and that exceeds the steering center is performed through the countersteering and then the turning direction of the vehicle body becomes opposite. At that time, the braking control amount is generated at at least one of the new front and rear turning outer wheels to generate yaw moment in a direction opposite to the direction of the excessive yaw moment in the vehicle body. Thus, the vehicle 10 is turned while the behavior of the vehicle 10 is stabilized and an excessive roll amount is suppressed.

[0040] Here, for example, when the steering angle δ of the steering wheel 21 in the last steering operation before countersteering is relatively large, roll moment and yaw moment that act on the vehicle body with the inversion of the turning direction through countersteering are larger than roll moment and yaw moment when the steering angle δ of the steering wheel 21 in the last steering operation before countersteering is relatively small. Furthermore, when the steering angular velocity ω_{str} at the time of countersteering from the last steering operation is relatively large, roll moment and yaw moment that act on the vehicle body with the inversion of the turning direction through countersteering are larger than roll moment and yaw moment when the steering angular velocity ω_{str} at the time of countersteering from the last steering operation is relatively small. Then, when the steering angle δ is larger than or equal to a predetermined value and the steering angular velocity ω_{str} is higher than or equal to a predetermined value, yaw moment that should be generated by the braking control amount FF_{out} of the turning outer wheel may be assumed to be relatively large. Therefore, the braking control amounts FF_{out} and FR_{out} for spin control may have to be generated at the front and rear turning outer wheels after the turning direction is inverted. In contrast to this, when the steering angle δ is smaller than the predetermined value and the steering angular velocity ω_{str} is lower than the predetermined value, yaw moment that should be generated by the braking control amount at the turning outer wheel is small as compared with when the steering angle δ is larger than or equal to the predetermined value and the steering angular velocity ω_{str} is higher than or equal to the predetermined value. Thus, the braking control amount FF_{out} for spin control just needs to be generated at the front

turning outer wheel only. Note that the respective predetermined values, for example, thresholds that vary with a vehicle center of gravity position, or the like, and vary on the basis of a vehicle type. Also, the respective predetermined values may be set on the basis of a vehicle-mounted state.

5 **[0041]** For this reason, the vehicle behavior control device is required to generate the braking control amounts with a high response at the control target wheels that will be new turning outer wheels with the inversion of the turning direction. Therefore, preliminary brake pressure control is preferably executed in a state where new turning outer wheels are still turning inner wheels. In the present embodiment, when the
10 condition that the braking control amounts are respectively generated at the front and rear turning outer wheels is satisfied, preliminary brake pressure is applied to at least one of the front and rear turning inner wheels.

[0042] Preliminary brake pressure control will be described more specifically. When the braking control amounts FF_{out} and FR_{out} for spin control need to be
15 respectively generated at new front and rear turning outer wheels, it is required to execute spin control with a high response even for sudden countersteering. Therefore, preliminary brake pressure is preferably applied in advance to the new front and rear turning outer wheels when they are still turning inner wheels in the last steering operation. However, at the time when preliminary brake pressure control is started, it is difficult to
20 accurately determine whether opposite steering operation performed after the last steering operation is countersteering that exceeds the steering center or returning operation to the steering center. On the other hand, in spin control, it may be assumed to be able to sufficiently stabilize vehicle behavior only by generating the braking control amount FF_{out} for spin control at the front turning outer wheel. This is because it is less frequent
25 that excessive roll moment and yaw moment act to require the braking control amount FR_{out} for spin control to be generated at the rear turning outer wheel. Thus, when preliminary brake pressure is applied to the rear turning outer wheel that is less likely to become the control target wheel, it may lead to deterioration in fuel economy because of driving of the pressure pump 69 (70).

[0043] As described above, when the braking control amount FRout for spin control is currently generated at the rear turning outer wheel, it may be required to execute spin control similar to the current spin control at the time when the turning direction is inverted through countersteering. At this time, the braking control amounts FFout and FRout for spin control may have to be respectively generated at the front and rear turning outer wheels. However, when preliminary brake pressure is applied at the time when opposite steering operation is not countersteering but returning operation, fuel economy deteriorates. Then, in the present embodiment, in the case where the braking control amount FRout for spin control is currently generated at the rear turning outer wheel, preliminary brake pressure is applied to only the current front turning inner wheel. The current front turning inner wheel will be a front turning outer wheel when the turning direction is inverted. That is, the vehicle behavior control device according to the present embodiment starts preliminary brake pressure control when the braking control amount FRout for spin control is generated at the rear turning outer wheel by anticipating that the turning direction will be inverted through countersteering although it is not clear whether the turning direction of the vehicle body is actually inverted thereafter. On the other hand, in the present embodiment, in consideration of deterioration of fuel economy, preliminary brake pressure control is executed over only the current front turning inner wheel. In this case, the inversion of the turning direction is anticipated by assuming the driver's opposite steering operation as countersteering.

[0044] The preliminary brake pressure (hereinafter, also referred to as "anticipated preliminary brake pressure") is, for example, a brake fluid pressure that does not apparently decrease the rotation speed of the control target wheel. In other words, the anticipated preliminary brake pressure is a brake fluid pressure by which, when a brake fluid pressure higher than or equal to the anticipated preliminary brake pressure is applied, the braking control amount corresponding to the brake fluid pressure may be generated with a high response. The anticipated preliminary brake pressure is output by controlling the brake actuator 35.

[0045] For example, as shown in the flow chart of FIG. 3, the vehicle behavior

control device initially determines whether an execution allowable condition that spin control is allowed to be executed is satisfied (step ST1). This determination is to determine whether it is required to execute over-steering suppressing control. That is, the determination may be carried out by employing a known execution allowable condition in the spin control. For example, when yaw moment is larger than a predetermined threshold, the vehicle behavior control device determines that the execution allowable condition for spin control is satisfied.

[0046] When the execution allowable condition for spin control is satisfied, the vehicle behavior control device sets the target braking control amounts (target wheel braking torques, target wheel braking forces) of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} for spin control (step ST2). In spin control, as described above, braking force is generated at at least one of the front and rear turning outer wheels. Therefore, the target braking control amount of the at least one control target wheel (at least one of the front and rear turning outer wheels) at which braking force is generated is set at a positive value. In contrast, the target braking control amounts of the front and rear turning inner wheels at which no braking force is generated are set at zero. Here, the target braking control amount $FFout0$ of the front turning outer wheel is set at $A (> 0)$, the target braking control amount $FRout0$ of the rear turning outer wheel is set at $B (> 0)$, the target braking control amount $FFin0$ of the front turning inner wheel is set at 0, and the target braking control amount $FRin0$ of the rear turning inner wheel is set at 0.

[0047] The vehicle behavior control device determines whether the braking control amount $FRout$ is also generated at the rear turning outer wheel through spin control ($FRout > 0 ?$) (step ST3). Here, because the target braking control amount $FRout0$ of the rear turning outer wheel is set at $B (> 0)$, the vehicle behavior control device sets a preliminary brake pressure control start flag F_s as the braking control amount $FRout$ is generated ($F_s = ON$) (step ST4). By so doing, the vehicle behavior control device applies the anticipated preliminary brake pressure to the front turning inner wheel that may be a turning outer wheel subsequently.

[0048] On the other hand, the vehicle behavior control device clears the

preliminary brake pressure control start flag F_s when the braking control amount FR_{out} is not generated at the rear turning outer wheel ($F_s = OFF$) (step ST5).

[0049] Hereinafter, a specific example of the preliminary brake pressure control will be described.

5 **[0050]** The vehicle behavior control device sets a preliminary brake pressure control mode M to an anticipated preliminary brake pressure control mode $M1$ (described in detail later) or a normal preliminary brake pressure control mode $M3$ (described in detail later), and executes preliminary brake pressure control in any one of the control modes. Furthermore, when no anticipated preliminary brake pressure is applied in the
10 anticipated preliminary brake pressure control mode $M1$, the vehicle behavior control device sets the preliminary brake pressure control mode M to a preliminary brake pressure off mode $M1_{off}$ (described in detail later). In addition, when no preliminary brake pressure (hereinafter, also referred to as "normal preliminary brake pressure") is applied in the normal preliminary brake pressure control mode $M3$, the vehicle behavior
15 control device sets the preliminary brake pressure control mode M to a preliminary brake pressure off mode $M3_{off}$ (described in detail later).

[0051] The anticipated preliminary brake pressure control mode $M1$ is a control mode of the anticipated preliminary brake pressure, described above using the flow chart of FIG. 3. That is, the preliminary brake pressure control mode $M1$ is a control mode
20 for increasing the control response of preliminary brake pressure control or spin control particularly at the time when quick countersteering is performed. Thus, in the anticipated preliminary brake pressure control mode $M1$, when the brake fluid pressure is increased in a state where the anticipated preliminary brake pressure is applied, the anticipated preliminary brake pressure is set so that the braking control amount is
25 immediately generated. In the anticipated preliminary brake pressure control mode $M1$, when the braking control amount FR_{out} for spin control is generated at the rear turning outer wheel and countersteering is anticipated to be being performed, the anticipated preliminary brake pressure is applied to the front turning inner wheel in synchronization with the output of the braking control amount FR_{out} . However, the anticipated

countersteering includes not only quick countersteering but also countersteering that is performed relatively slowly.

[0052] The anticipated preliminary brake pressure control mode M1 prepares an anticipated right front wheel control mode M1FR and an anticipated left front wheel control mode M1FL. The anticipated right front wheel control mode M1FR is a control mode in which the anticipated preliminary brake pressure is applied to the braking device 37_{FR} of the right front wheel W_{FR}. The anticipated left front wheel control mode M1FL is a control mode in which the anticipated preliminary brake pressure is applied to the braking device 37_{FL} of the left front wheel W_{FL}.

[0053] When the anticipated right front wheel control mode M1FR is set, the vehicle behavior control device controls the brake actuator 35 to apply the anticipated preliminary brake pressure to the right front wheel W_{FR}. At this time, the vehicle behavior control device closes the master cut valve 42 and the pressure reducing valve 58, which are associated with the right front wheel W_{FR}, opens the retention valve 50 and drives the electric motor 68 and the pressure pump 69 in the brake actuator 35 such that the anticipated preliminary brake pressure is applied to the braking device 37_{FR} of the right front wheel W_{FR}. The brake actuator 35 at that time is controlled so as to close the master cut valve 43, the retention valves 51, 52 and 53 and the pressure reducing valves 59, 60 and 61, which are associated with the other wheels W_{FL}, W_{RL} and W_{RR}. That is, the brake actuator 35 is controlled such that braking force does not work on (that is, the anticipated preliminary brake pressure is not applied to) the other wheels W_{FL}, W_{RL} and W_{RR}.

[0054] In addition, when the anticipated left front wheel control mode M1FL is set, the vehicle behavior control device controls the brake actuator 35 to apply the anticipated preliminary brake pressure to the left front wheel W_{FL}. At this time, the vehicle behavior control device closes the master cut valve 43 and the pressure reducing valve 61 associated with the left front wheel W_{FL}, opens the retention valve 53 and drives the electric motor 68 and the pressure pump 70 in the brake actuator 35 so that the anticipated preliminary brake pressure is applied to the braking device 37_{FL} of the left

front wheel W_{FL} . The brake actuator 35 at that time is controlled so as to close the master cut valve 42, the retention valves 50, 51 and 52 and the pressure reducing valves 58, 59 and 60, which are associated with the other wheels W_{FR} , W_{RL} and W_{RR} . That is, the brake actuator 35 is controlled such that braking force does not work on (that is, the anticipated preliminary brake pressure is not applied to) the other wheels W_{FR} , W_{RL} and W_{RR} .

[0055] On the other hand, the normal preliminary brake pressure control mode M3 corresponds to an existing preliminary brake pressure control mode, and is, for example, a control mode in which a preliminary brake pressure lower than the anticipated preliminary brake pressure to be generated in the anticipated preliminary brake pressure control mode M1 may be applied. The normal preliminary brake pressure control mode M3 prepares a master valve close mode M3a and a motor drive mode M3b.

[0056] The master valve close mode M3a is a mode in which the master cut valve 42 (43) and the pressure reducing valve 58 (59, 60 or 61) of the control target wheel to which the normal preliminary brake pressure is applied are closed, the retention valve 50 (51, 52 or 53) of the control target wheel is opened and the electric motor 68 and the pressure pump 70 are driven to thereby apply the normal preliminary brake pressure to the control target wheel.

[0057] The motor drive mode M3b is a mode in which the master cut valve 42 (43) of the control target wheel is opened in the master valve close mode M3a and a normal preliminary brake pressure lower than that in the master valve close mode M3a is generated.

[0058] In addition, when the preliminary brake pressure off mode M1off or M3off is set, the vehicle behavior control device controls the brake actuator 35 so as not to cause braking force to work on (apply preliminary brake pressure to) the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} . At this time, the vehicle behavior control device executes control such that at least the electric motor 68 and the pressure pumps 69 and 70 are not driven in the brake actuator 35.

[0059] Hereinafter, a specific example of processing operations (preliminary

brake pressure control) of the vehicle behavior control device according to the present embodiment will be described in detail with reference to the flow charts shown in FIG. 4 and FIG. 5.

[0060] Initially, as shown in the flow chart of FIG. 4, the vehicle behavior control device determines whether preliminary brake pressure control is allowed to be executed (step ST10). The determination in step ST10 considers whether there is an obstacle to execute preliminary brake pressure control. For example, in step ST10, during not braking and when the braking system and sensors required for ABS control, VSC control, and the like, function normally, the vehicle behavior control device determines that "preliminary brake pressure control is allowed to be executed".

[0061] When preliminary brake pressure control is not allowed to be executed, the vehicle behavior control device sets the preliminary brake pressure control mode M to the preliminary brake pressure off mode M1off (step ST15). On the other hand, when preliminary brake pressure control is allowed to be executed, the vehicle behavior control device determines whether the preliminary brake pressure control mode M is set to the preliminary brake pressure off mode M1off (step ST20). Note that, in an initial state, for example, the preliminary brake pressure control mode M is set to the preliminary brake pressure off mode M1off. Here, the initial state is, for example, a state where preliminary brake pressure control is not executed once after ignition is turned on.

[0062] When the preliminary brake pressure control mode M is not set to the preliminary brake pressure off mode M1off, the vehicle behavior control device causes the process to proceed to step ST70 (described later). In contrast to this, when the preliminary brake pressure control mode M is set in the preliminary brake pressure off mode M1off, the vehicle behavior control device determines whether the execution allowable condition for spin control is satisfied as in the case of the above described step ST1 (step ST25).

[0063] When the execution allowable condition for spin control is not satisfied, the vehicle behavior control device causes the process to proceed to step ST70 (described later). In contrast to this, when the execution allowable condition for spin control is

satisfied, the vehicle behavior control device sets the target braking control amounts of the wheels W_{FL} , W_{FR} , W_{RL} and W_{RR} for spin control as in the case of the above described step ST2 (step ST30). Then, the vehicle behavior control device determines whether the braking control amount FR_{out} is generated at the rear turning outer wheel as the spin
5 control is executed ($FR_{out} > 0$?) (step ST35).

[0064] When the braking control amount FR_{out} is generated, the vehicle behavior control device determines whether the vehicle 10 is turning rightward and the steering angular velocity ω_{str} at that time is a positive value (step ST40). That is, the vehicle behavior control device determines whether the steering wheel 21 is steered in an
10 opposite direction (counterclockwise direction) during rightward turning.

[0065] Then, when the steering angular velocity ω_{str} is a positive value during rightward turning, the vehicle behavior control device sets the preliminary brake pressure control mode M to the anticipated right front wheel control mode $M1FR$. Then, the vehicle behavior control device applies the anticipated preliminary brake pressure to the
15 right front wheel W_{FR} that is the current front turning inner wheel (step ST45). That is, when steering operation in a direction opposite to the turning direction is performed during rightward turning, the vehicle behavior control device is hard to determine whether the opposite steering operation is returning operation to the steering center or countersteering that exceeds the steering center, but the vehicle behavior control device
20 anticipates the opposite steering operation as countersteering and applies anticipated preliminary brake pressure to the right front wheel W_{FR} . The right front wheel W_{FR} will be the next front turning outer wheel as the turning direction is inverted through the countersteering. The vehicle behavior control device causes the process to proceed to step ST70 (described later) thereafter.

[0066] In contrast to this, when the steering angular velocity ω_{str} is not a
25 positive value during rightward turning, the vehicle behavior control device determines whether the vehicle 10 is turning leftward and the steering angular velocity ω_{str} at that time is a negative value (step ST50). That is, the vehicle behavior control device determines whether the steering wheel 21 is steered in an opposite direction (clockwise

direction) during leftward turning.

[0067] When the steering angular velocity ω_{str} is a negative value during leftward turning, the vehicle behavior control device sets the preliminary brake pressure control mode M to the anticipated left front wheel control mode M1FL. Then, the vehicle behavior control device applies the anticipated preliminary brake pressure to the left front wheel W_{FL} that is the current front turning inner wheel (step ST55). That is, when steering operation in a direction opposite to the turning direction is performed during leftward turning, the vehicle behavior control device is hard to determine whether the opposite steering operation is returning operation to the steering center or countersteering that exceeds the steering center, but the vehicle behavior control device anticipates the opposite steering operation as countersteering and applies anticipated preliminary brake pressure to the left front wheel W_{FL} . The wheel W_{FL} will be the next front turning outer wheel as the turning direction is inverted through the countersteering. The vehicle behavior control device causes the process to proceed to step ST70 (described later) thereafter.

[0068] When negative determination is made in step ST50, it is assumed to be apparent that the driver is not performing countersteering, and the vehicle behavior control device causes the process to proceed to step ST70 (described later).

[0069] On the other hand, when no braking control amount FRout for spin control is generated at the rear turning outer wheel, the vehicle behavior control device determines: whether the absolute value of the detected steering angle δ is smaller than a predetermined threshold $Th\delta$ (> 0) and the absolute value of the calculated steering angular velocity ω_{str} is smaller than a predetermined threshold $Th\omega_{str2}$ (> 0); and whether the absolute value of the detected steering angle δ is smaller than a predetermined threshold $Th\delta$ (> 0) and the absolute value of the calculated yaw angular acceleration α_y is smaller than a predetermined threshold $Th\alpha_y2$ (> 0) (step ST60). In step ST60, affirmative determination is made when the absolute value of the steering angle δ is smaller than the predetermined threshold $Th\delta$ and the absolute value of the steering angular velocity ω_{str} is smaller than the predetermined threshold $Th\omega_{str2}$ or

when the absolute value of the steering angle δ is smaller than the predetermined threshold $Th\delta$ and the absolute value of the yaw angular acceleration α_y is smaller than the predetermined threshold $Th\alpha_y2$; otherwise, negative determination is made.

[0070] When affirmative determination is made in step ST60, the vehicle behavior control device determines that the opposite steering operation is returning operation for returning the steering wheel 21 to the steering center. Therefore, the vehicle behavior control device at this time sets the preliminary brake pressure control mode M to the preliminary brake pressure off mode M1off (step ST65), and then causes the process to proceed to step ST70 (described later). In contrast to this, when negative determination is made in step ST60, for example, the steering angular velocity ω_{str} is high, so countersteering may be performed. Thus, the vehicle behavior control device causes the process to proceed to step ST70 without setting the preliminary brake pressure off mode M1off.

[0071] After the vehicle behavior control device ends processings in the flow chart of FIG. 4, the vehicle behavior control device executes processings in and after step ST70 shown in the flow chart of FIG. 5. The vehicle behavior control device determines whether the last preliminary brake pressure control mode M2 is not the preliminary brake pressure off mode M1off and the current preliminary brake pressure control mode M is the preliminary brake pressure off mode M1off (step ST70). In step ST70, affirmative determination is made when the last preliminary brake pressure control mode M2 is the anticipated right front wheel control mode M1FR or the anticipated left front wheel control mode M1FL and the current preliminary brake pressure control mode M is the preliminary brake pressure off mode M1off; otherwise, negative determination is made. For example, in step ST70, the anticipated preliminary brake pressure control mode M1 is set for the first time (that is, the last preliminary brake pressure control mode M2 is not determined) or while anticipated preliminary brake pressure control is being continued (both the last preliminary brake pressure control mode M2 and the current preliminary brake pressure control mode M each are the anticipated preliminary brake pressure control mode M1), negative determination is made.

[0072] The case where affirmative determination is made in step ST70 is the case where anticipated preliminary brake pressure control is executed once and the subsequent steering operation may be determined as returning operation for returning the steering wheel 21 to the steering center. Therefore, when the last preliminary brake pressure control mode M2 is not the preliminary brake pressure off mode M1off and the current preliminary brake pressure control mode M is the preliminary brake pressure off mode M1off, the vehicle behavior control device sets an anticipated preliminary brake pressure control once operation flag (hereinafter, referred to as "anticipated operation flag") F1 (F1 = ON) (step ST75). The anticipated operation flag F1 indicates that anticipated preliminary brake pressure control has been executed once.

[0073] Subsequently, after the vehicle behavior control device makes negative determination in step ST70 or sets the anticipated operation flag F1 in step ST75, the vehicle behavior control device determines whether the anticipated operation flag F1 is set (step ST80). In step ST80, affirmative determination is made when step ST75 has been passed, and negative determination is made when negative determination is made in step ST70. The case where negative determination is made in step ST70 is, for example, the case where the anticipated right front wheel control mode M1FR or the anticipated left front wheel control mode M1FL is set.

[0074] When the anticipated operation flag F1 is set, the vehicle behavior control device counts a period of time during which the anticipated operation flag F1 is set (hereinafter, referred to as "anticipated operation flag elapsed time") C1 ($C1 = C1 + 1$) (step ST85).

[0075] Subsequently, after the vehicle behavior control device makes negative determination in step ST80 or counts the anticipated operation flag elapsed time C1 in step ST85, the vehicle behavior control device determines whether the anticipated operation flag elapsed time C1 exceeds a predetermined period of time T1 (step ST90). The predetermined period of time T1 is a maximum period of time during which execution of anticipated preliminary brake pressure control is prohibited. That is, the determination in step ST90 is to prohibit execution of anticipated preliminary brake

pressure control until the anticipated operation flag elapsed time C1 exceeds the predetermined period of time T1 when anticipated preliminary brake pressure control is executed once and subsequently returning operation for returning the steering wheel 21 to the steering center is performed. In step ST90, negative determination is made not only
5 when the anticipated operation flag elapsed time C1 counted in step ST85 does not exceed the predetermined period of time T1 but also when it is determined in step ST80 that the anticipated operation flag F1 is not set. When the anticipated operation flag F1 is not set in step ST80 is, for example, when the preliminary brake pressure control mode M is set to the anticipated right front wheel control mode M1FR or to the anticipated left
10 front wheel control mode M1FL.

[0076] When the anticipated operation flag elapsed time C1 exceeds the predetermined period of time T1, the vehicle behavior control device clears the anticipated operation flag F1 (F1 = OFF), and resets the anticipated operation flag elapsed time C1 (C1 = 0) (step ST95). By so doing, when countersteering is performed
15 again after returning operation for returning the steering wheel 21 to the steering center, anticipated preliminary brake pressure control that has been prohibited for a set period of time (= predetermined period of time T1) may be executed again.

[0077] Subsequently, after the vehicle behavior control device makes negative determination in step ST90 or passes through step ST95, the vehicle behavior control
20 device sets the current preliminary brake pressure control mode M to the last preliminary brake pressure control mode M2 (step ST100).

[0078] Then, the vehicle behavior control device determines whether the newly set last preliminary brake pressure control mode M2 is not the preliminary brake pressure off mode M1off and the anticipated operation flag F1 is cleared (step ST105).

25 [0079] When the last preliminary brake pressure control mode M2 is the preliminary brake pressure off mode M1off and the anticipated operation flag F1 is cleared, the vehicle behavior control device sets the preliminary brake pressure control mode M to the master valve close mode M3a. Then, the vehicle behavior control device applies the normal preliminary brake pressure in the master valve close mode M3a to at

least one of the current front and rear turning inner wheels (step ST110).

[0080] In contrast to this, when negative determination is made in step ST105, the vehicle behavior control device determines whether a normal preliminary brake pressure control once operation flag (hereinafter, referred to as "normal operation flag")

5 F2 is set (step ST115). The normal operation flag F2 indicates that normal preliminary brake pressure control has been executed once. For example, the normal operation flag F2 is set at the time when normal preliminary brake pressure control has been completed.

[0081] When the normal operation flag F2 is set, the vehicle behavior control device counts a period of time during which the normal operation flag F2 is set
10 (hereinafter, referred to as "normal operation flag elapsed time") C2 ($C2 = C2 + 1$) (step ST120). Then, the vehicle behavior control device determines whether the normal operation flag elapsed time C2 is shorter than a predetermined period of time T2 (step ST125). The predetermined period of time T2 is a maximum period of time during which execution of normal preliminary brake pressure control is continued.

15 [0082] When the normal operation flag elapsed time C2 is shorter than the predetermined period of time T2, the process proceeds to step ST110. In step ST110, the vehicle behavior control device sets the preliminary brake pressure control mode M in the master valve close mode M3a. In the master valve close mode M3a, relatively high normal preliminary brake pressure may be applied, within the normal preliminary brake
20 pressure control mode M3. Then, the vehicle behavior control device applies the normal preliminary brake pressure in the master valve close mode M3a to at least one of the current front and rear turning inner wheels.

[0083] In contrast to this, when the normal operation flag elapsed time C2 is longer than or equal to the predetermined period of time T2, the vehicle behavior control
25 device sets the preliminary brake pressure control mode M in the motor drive mode M3b in which the normal preliminary brake pressure is lower than that in the master valve close mode M3a. Then, the vehicle behavior control device applies the normal preliminary brake pressure in the motor drive mode M3b to at least one of the current front and rear turning inner wheels (step ST130).

[0084] On the other hand, when the normal operation flag F2 is not set, the vehicle behavior control device sets the preliminary brake pressure control mode M to the preliminary brake pressure off mode M3off (step ST135).

[0085] When the driver performs steering operation that exceeds the steering center in a direction opposite to the current steering operation and the turning direction of the vehicle body is inverted, the vehicle behavior control device is able to generate the target braking control amounts for spin control with a high response at new turning outer wheels to which preliminary brake pressure is applied when the behavior of the vehicle requires spin control. Particularly, the vehicle behavior control device starts braking control over the rear turning outer wheel for spin control in the current turning, and applies anticipated preliminary brake pressure to the front turning inner wheel that may be the next turning outer wheel as the turning direction is inverted. That is, the vehicle behavior control device is able to add anticipated preliminary brake pressure to the front turning inner wheel in advance before the turning direction of the vehicle body is actually inverted. Therefore, with the vehicle behavior control device, even when quick output of preliminary brake pressure is required, for example, when countersteering from the current turning state is sudden steering, it is possible to quickly apply preliminary brake pressure before the vehicle body shifts into the next opposite turning. Thus, with the vehicle behavior control device, it is possible to generate the target braking control amount with a high response at the new front turning outer wheel after inversion of the turning direction. As a result, the control performance of spin control improves.

[0086] Furthermore, the vehicle behavior control device executes anticipated preliminary brake pressure control over the front turning inner wheel without taking into consideration the behavior of the vehicle through driver's opposite steering operation. That is, the vehicle behavior control device executes anticipated preliminary brake pressure control over the front turning inner wheel in a state where it is not clear whether the opposite steering operation is countersteering that exceeds the steering center or returning operation to the steering center. Therefore, when the anticipated preliminary brake pressure control is not required as well, the anticipated preliminary brake pressure

control may be executed. However, in spin control, for example, when it is found that the operation amount (steering angular velocity, or the like) of the driver's opposite steering operation does not correspond to countersteering, the braking control amount FRout generated at the rear turning outer wheel for spin control is set at zero. Thus, in this case, negative determination is made in step ST35, and affirmative determination is made in step ST60. Therefore, the preliminary brake pressure control mode M is set to the preliminary brake pressure off mode M1off, and anticipated preliminary brake pressure control over the front turning inner wheel is cancelled. Therefore, with the vehicle behavior control device, when anticipated preliminary brake pressure control is not required, anticipated preliminary brake pressure control is cancelled immediately after application of anticipated preliminary brake pressure, so it is possible to end the unnecessary anticipated preliminary brake pressure control in a short period of time. Thus, it is possible to reduce, for example, deterioration of fuel economy, or the like, when anticipated preliminary brake pressure control is not required while ensuring the control response when anticipated preliminary brake pressure control is required.

[0087] In addition, in the vehicle behavior control device, it is less frequent that the braking control amount for spin control is generated at the rear turning outer wheel. Therefore, in the vehicle behavior control device, anticipated preliminary brake pressure control is not executed over the rear turning inner wheel before the turning direction is inverted, and anticipated preliminary brake pressure control is executed over only the front turning inner wheel. Thus, with the vehicle behavior control device, it is possible to suppress an increase in the operation frequency of the brake actuator 35 for unnecessary anticipated preliminary brake pressure control. Note that, when it is highly frequent to generate the braking control amount for spin control at the rear turning outer wheel, anticipated preliminary brake pressure control may be executed over each of the front and rear turning inner wheels. Note that, steps ST1 to ST3 and ST5 may be regarded as the behavior stabilizing control unit. Furthermore, steps ST2 to ST4 and steps shown in FIG. 4 and FIG. 5 may be regarded as the preliminary brake pressure applying unit.

CLAIMS:

1. A vehicle behavior control device comprising:

a behavior stabilizing control unit that executes vehicle behavior stabilizing control in which a braking control amount is generated at at least one of front and rear turning outer wheels (W_{FL} , W_{RL} , W_{FR} , W_{RR}) to stabilize a behavior of a vehicle; and

a preliminary brake pressure applying unit that, when a condition for generating the braking control amounts at the front and rear turning outer wheels (W_{FL} , W_{RL} , W_{FR} , W_{RR}) is satisfied while the vehicle behavior stabilizing control is being executed, applies preliminary brake pressure to at least one of front and rear turning inner wheels (W_{FL} , W_{RL} , W_{FR} , W_{RR}).

2. The vehicle behavior control device according to claim 1, wherein the preliminary brake pressure applying unit detects steering operation in a direction opposite to a current turning direction of the vehicle while the vehicle behavior stabilizing control is being executed, and applies the preliminary brake pressure when the steering operation in the opposite direction has been detected.

3. The vehicle behavior control device according to claim 1 or 2, wherein the preliminary brake pressure applying unit applies the preliminary brake pressure to the front turning inner wheel (W_{FL} , W_{FR}) when the vehicle behavior stabilizing control is over-steering suppressing control.

4. The vehicle behavior control device according to claim 2, wherein the preliminary brake pressure applying unit determines whether the opposite steering operation is countersteering when the steering operation in the opposite direction has been detected, and cancels application of the preliminary brake pressure when it is determined that the steering operation in the opposite direction is not countersteering.

5. A vehicle behavior control method comprising:

executing vehicle behavior stabilizing control in which a braking control amount is generated at at least one of front and rear turning outer wheels (W_{FL} , W_{RL} , W_{FR} , W_{RR}) to stabilize a behavior of a vehicle; and

when a condition for generating the braking control amounts at the front and rear turning outer wheels (W_{FL} , W_{RL} , W_{FR} , W_{RR}) is satisfied while the vehicle behavior stabilizing control is being executed, applying preliminary brake pressure to at least one of front and rear turning inner wheels (W_{FL} , W_{RL} , W_{FR} , W_{RR}).

6. The vehicle behavior control method according to claim 5, further comprising:

detecting steering operation in a direction opposite to a current turning direction of the vehicle while the vehicle behavior stabilizing control is being executed, wherein the preliminary brake pressure is applied when the steering operation in the opposite direction has been detected.

7. The vehicle behavior control method according to claim 5 or 6, wherein the preliminary brake pressure is applied to the front turning inner wheel (W_{FL} , W_{FR}) when the vehicle behavior stabilizing control is over-steering suppressing control.

8. The vehicle behavior control method according to claim 6, further comprising:

determining whether the opposite steering operation is countersteering when the steering operation in the opposite direction has been detected; and

cancelling application of the preliminary brake pressure when it is determined that the steering operation in the opposite direction is not countersteering.

FIG. 1

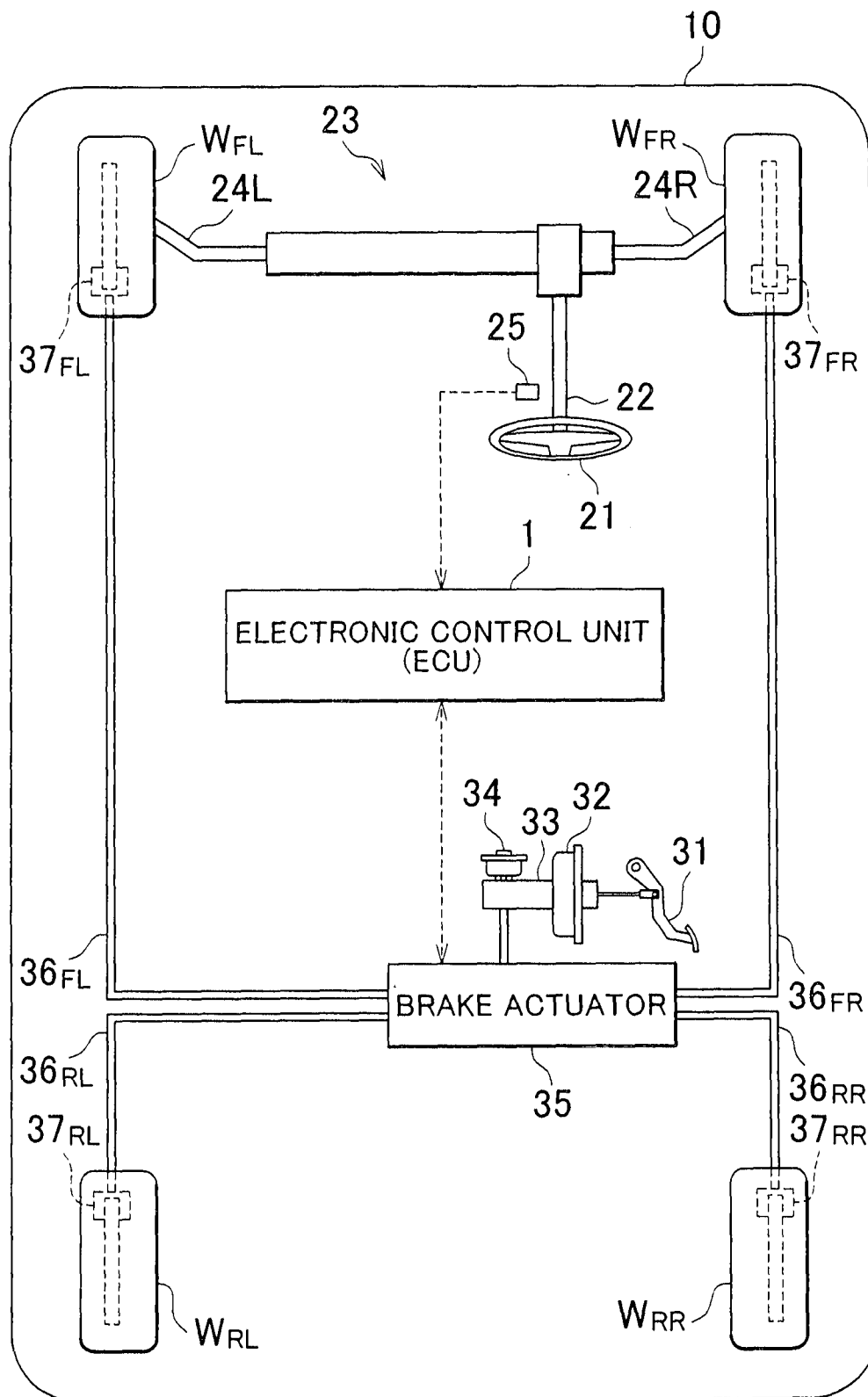


FIG. 2

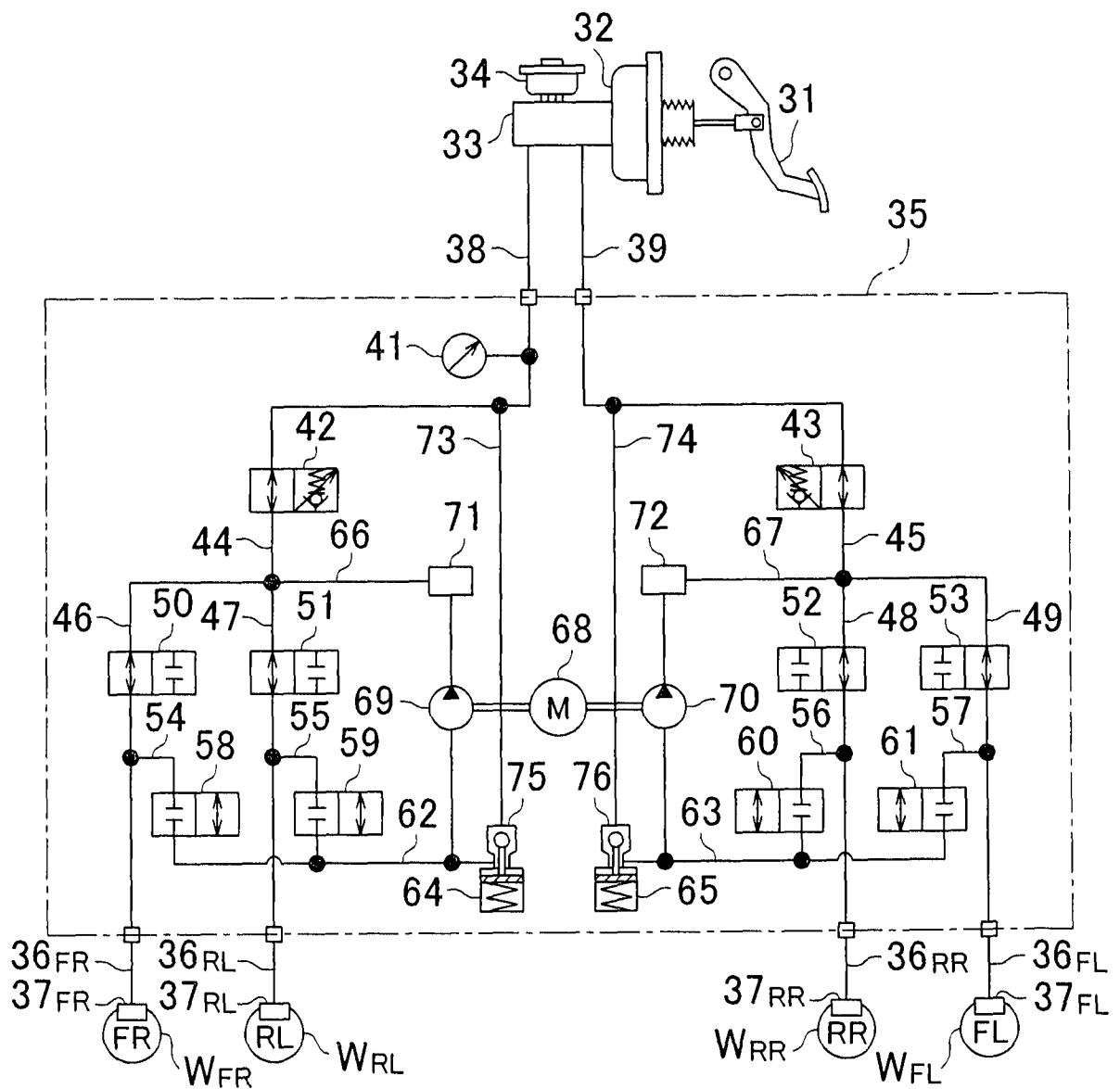


FIG. 3

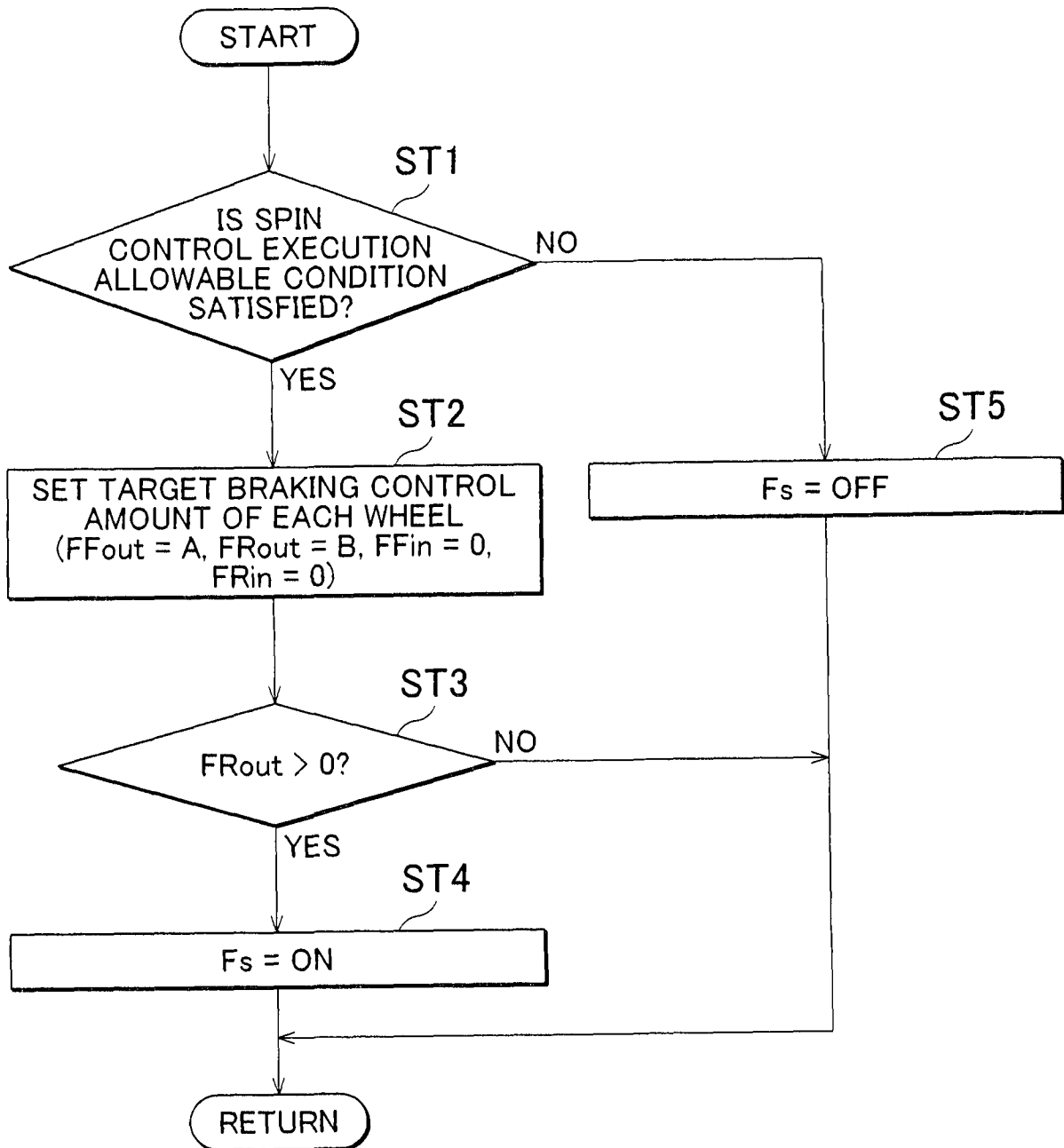


FIG. 4

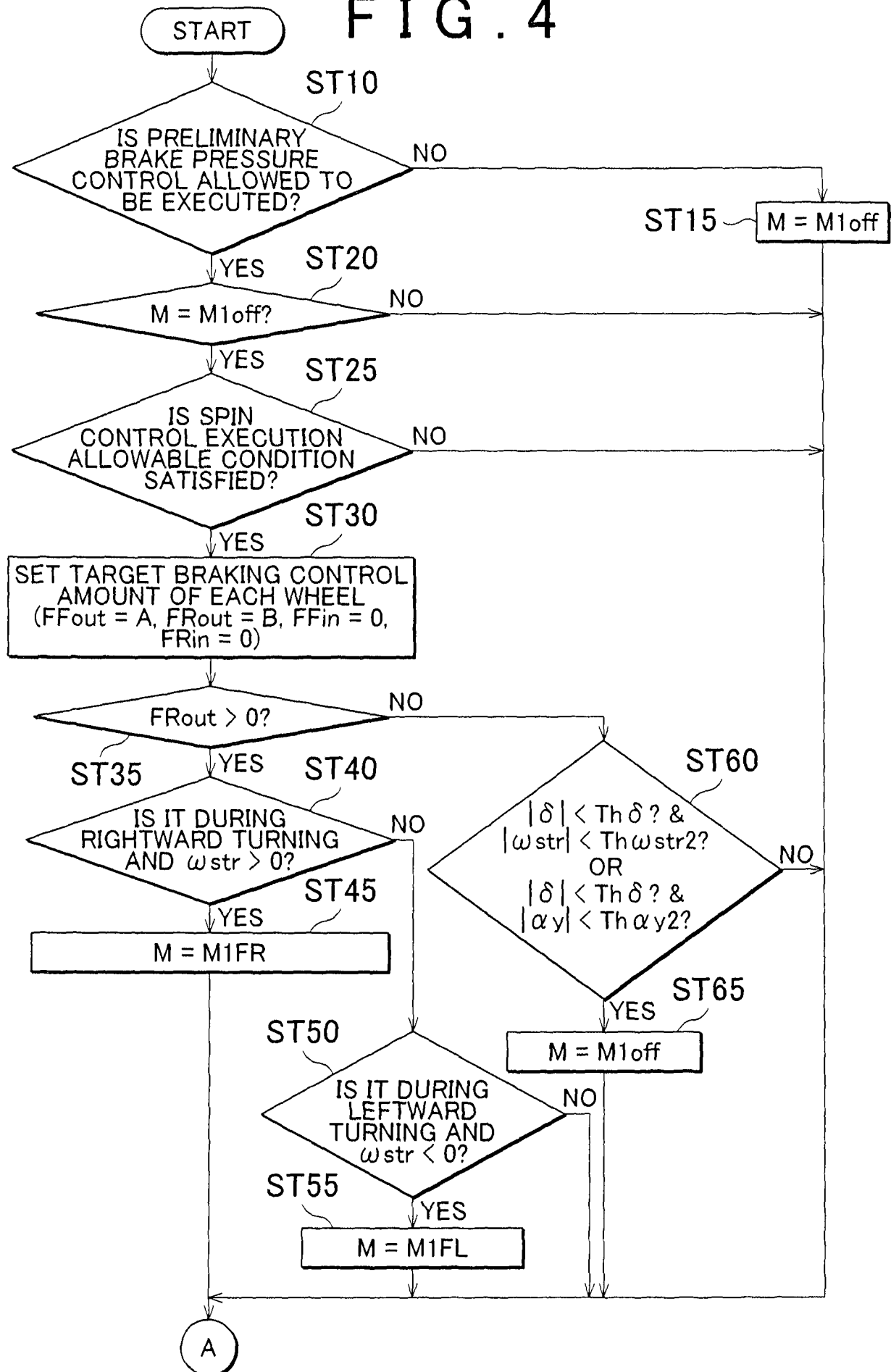
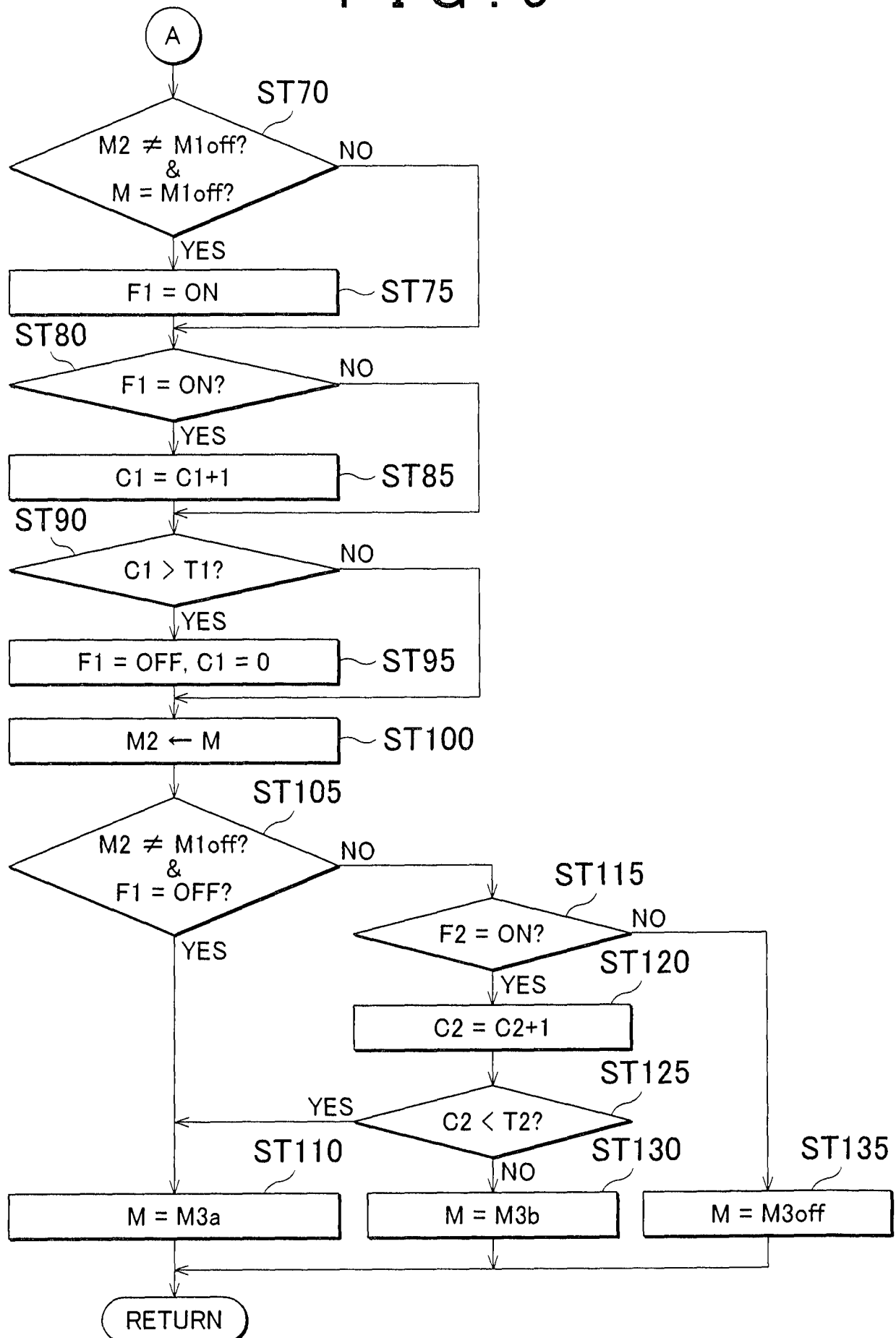


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/001422

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60T8/1755
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)
B60T

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

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X	DE 10 2004 040140 A1 (BOSCH GMBH ROBERT [DE]) 23 February 2006 (2006-02-23) paragraph [0036]	1-3,5-7
X	WO 2005/054022 A1 (BOSCH GMBH ROBERT [DE]; NIMMO MATTHEW [DE]; HEY MATTHIAS [DE]) 16 June 2005 (2005-06-16) page 2, line 5 - line 27 page 4, line 22 - line 41	1-3,5-7
X	EP 1 201 519 A1 (MAZDA MOTOR [JP]; SUMITOMO ELECTRIC INDUSTRIES [JP]) 2 May 2002 (2002-05-02) paragraph [0145] - paragraph [0146]	1-3,5-7
X	WO 2010/070738 A1 (TOYOTA MOTOR CO LTD [JP]; WATANABE RYOCHI [JP]) 24 June 2010 (2010-06-24) figures 3-6 -/-	1-8

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

☒ See patent family annex.

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Date of the actual completion of the international search

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International application No

PCT/IB2012/001422

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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