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Abstract

The present invention provides a control device that controls a suspension mechanism of a straddle type vehicle, comprising: a wheel speed sensor configured to detect a wheel speed of the straddle type vehicle; an estimation unit configured to estimate a stroke speed of the suspension mechanism, based on a change in the wheel speed detected by the wheel speed sensor; and a correction unit configured to correct the stroke speed estimated by the estimation unit, in accordance with a circumferential length of a grounding part of a tire changed by turning of the straddle type vehicle.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of International Patent Application No. PCT/JP2023/003187 filed on Feb. 1, 2023, which claims priority to and the benefit of Japanese Patent Application No. 2022-014410 filed on Feb. 1, 2022, the entire disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION
Field of the Invention
(1) The present invention relates to a control technique of a vehicle.
Description of the Related Art
(2) In these years, in order to improve steering stability and riding comfort, a suspension mechanism of a damping force variable type capable of variably controlling damping force is used on a vehicle, and so-called skyhook control for controlling the damping force of the suspension mechanism using a skyhook theory can be conducted (see Japanese Patent No. 6130816). As a method for controlling the damping force of the suspension mechanism, there are known methods such as a method for changing the viscosity of a magneto-rheological fluid used as hydraulic oil, and a method for changing the diameter of an orifice through which the hydraulic oil passes. However, in the suspension mechanism, even in a case where the viscosity of the magneto-rheological fluid or the diameter of the orifice is constant, the damping force changes in accordance with a stroke speed. Hence, it is important to accurately obtain the stroke speed in order to accurately conduct the skyhook control.
(3) Japanese Patent No. 6130816 describes a method for obtaining a stroke speed of a four-wheeled vehicle. On the other hand, in a straddle type vehicle (for example, a two-wheeled vehicle), a tread surface of a tire has a curved shape, and thus a circumferential length of a grounding part of the tire changes in accordance with turning of the straddle type vehicle, and an error may occur in the stroke speed in accordance with a change in the circumferential length. That is, in the straddle type vehicle, in a case where it is possible to obtain the stroke speed of the suspension mechanism in a more accurate manner, there is room for further improving the steering stability and the riding comfort.
SUMMARY OF THE INVENTION
(4) The present invention provides, for example, a technique capable of accurately obtaining a stroke speed of a suspension mechanism of a straddle type vehicle.
(5) According to the present invention, there is provided a control device that controls a suspension mechanism of a straddle type vehicle, comprising: a wheel speed sensor configured to detect a wheel speed of the straddle type vehicle; an estimation unit configured to estimate a stroke speed of the suspension mechanism, based on a change in the wheel speed detected by the wheel speed sensor; and a correction unit configured to correct the stroke speed estimated by the estimation unit, in accordance with a circumferential length of a grounding part of a tire changed by turning of the straddle type vehicle.
(6) Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a left side view of a straddle type vehicle.
(2) FIG. **2** is a diagram in which a vibration reduction mechanism is modeled.
(3) FIG. **3** is a diagram illustrating a configuration example of a control device.
(4) FIG. **4** is a block diagram illustrating estimation of a stroke speed in the control device.
(5) FIG. **5** is a flowchart illustrating processing performed by a correction unit of the control device.

DESCRIPTION OF THE EMBODIMENTS

(6) Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention, and limitation is not made to an invention that requires a combination of all features described in the embodiments. Two or more of the multiple features described in the embodiments may be combined as appropriate. Furthermore, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

(7) [Outline of Straddle Type Vehicle]

(8) FIG. **1** is a left side view of a straddle type vehicle **1** according to an embodiment of the present invention. In FIG. **1**, arrows X, Y, and Z indicate directions orthogonal to one another. X direction indicates a front-and-rear direction of the straddle type vehicle **1**, Y direction indicates a vehicle width direction (left-and-right direction) of the straddle type vehicle **1**, and Z direction indicates an up-and-down direction of the straddle type vehicle **1**. Hereinafter, an example in which a control device according to the present invention is applied to a two-wheeled motor vehicle as the straddle type vehicle **1** will be described. However, the control device according to the present invention is applicable to other types of straddle type vehicles such as three-wheeled vehicles, and is also applicable to electric vehicles with motors as drive sources, in addition to vehicles with internal combustion engines as the drive sources. Note that in the following, the straddle type vehicle **1** will be referred to as the vehicle **1**, in some cases.

(9) The vehicle **1** includes a power unit **2** between a front wheel FW and a rear wheel RW. The power unit **2** includes an engine **21** and a transmission **22**. Drive force of the transmission **22** is transmitted to the rear wheel RW via a drive shaft, not illustrated, to rotate the rear wheel RW.

(10) The power unit **2** is supported by a vehicle body frame **3**. The vehicle body frame **3** includes a pair of left and right main frames **31**, which extend in X direction. A fuel tank **5** and an air cleaner box (not illustrated) are disposed above the main frames **31**. A meter unit MU for displaying various types of information to an occupant (rider) is provided on a front side of the fuel tank **5**.

(11) On front end portions of the main frames **31**, a head pipe **32**, which rotatably supports a steering shaft (not illustrated) to be rotated by a handlebar **8**, is provided. On rear end portions of the main frames **31**, a pair of left and right pivot plates **33** are respectively provided. Lower end portions of the pivot plates **33** and front end portions of the main frames **31** are connected by a pair of left and right lower arms (not illustrated), and the power unit **2** is supported by the main frames **31** and the lower arms. A pair of left and right seat rails that extend rearward are also provided at the rear end portions of the main frames **31**, and a seat **4***a*, on which a rider is seated, a seat **4***b* on which a passenger is seated, a rear trunk **7***b*, and the like are supported on the seat rails.

(12) A front end portion of a rear swing arm (not illustrated) that extends in the front-and-rear direction is swingably supported by the pivot plates **33**. The rear swing arm is swingable in the up-and-down direction, and the rear wheel RW is supported on its rear end portion. An exhaust muffler **6**, which muffles exhaust of the engine **21**, extends in X direction on a lower lateral side of the rear wheel RW. On upper lateral sides of the rear wheel RW, left and right saddlebacks **7***a* are respectively provided.

(13) In the front end portions of the main frames **31**, a front suspension mechanism **9**, which swingably supports the front wheel FW, is constituted. The front suspension mechanism **9** includes

an upper link **91**, a lower link **92**, a fork support body **93**, a vibration reduction mechanism **94** (cushion unit), and a pair of left and right front forks **95**. In the front suspension mechanism **9**, the upper link **91**, the lower link **92**, the fork support body **93**, and the vibration reduction mechanism **94** constitute a support mechanism for supporting the front forks **95** of the vehicle **1**.

(14) The upper link **91** and the lower link **92** are vertically disposed in the front end portions of the main frames **31**. Rear end portions of the upper link **91** and the lower link **92** are swingably coupled with the front end portions of the main frames **31**, respectively. The upper link **91** and the lower link **92** are swingably coupled with the fork support body **93**.

(15) The fork support body **93** has a tubular shape, and is inclined rearward. A steering shaft **96** is supported by the fork support body **93** so as to be rotatable about the axis of the steering shaft **96**. The steering shaft **96** includes a shaft portion (not illustrated) into which the fork support body **93** is inserted. A bridge (not illustrated) is provided in a lower end portion of the steering shaft **96**, and the pair of left and right front forks **95** are supported by such a bridge. The front forks **95** rotatably support the front wheel FW, and also supports a front brake FB. An upper end portion of the steering shaft **96** is coupled with a steering shaft (not illustrated) rotated by the handlebar **8** via a link **97**. An upper portion of the front wheel FW is covered with a fender **10**, and the fender **10** is supported by the front forks **95**.

(16) Next, the vibration reduction mechanism **94** of the front suspension mechanism **9** will be described. FIG. **2** is a diagram in which the vibration reduction mechanism **94** is modeled. The vibration reduction mechanism **94** is a mechanism for reducing vibrations transmitted from the road (ground) to the vehicle **1** (vehicle body), and includes an elastic member **200** and a viscosity damping member **250**. As illustrated in FIG. **1**, the vibration reduction mechanism **94** is swingably supported at its upper end portion by the main frames **31**, and is swingably supported at its lower end portion by the lower link **92**.

(17) In FIG. **2**, an unsprung mass M**1** denotes a mass of the lower link **92**, by which a lower end of the vibration reduction mechanism **94** is supported, and constituent members connected with the lower link **92** (for example, the front wheel FW, the front brake FB, and the like). In addition, a sprung mass M**2** denotes a mass of the main frames **31**, by which an upper portion of the vibration reduction mechanism **94** is supported, and constituent members connected with the main frames **31** (for example, the vehicle body). A load F**1** denotes a grounding load (grounding load variation) to be input into the vibration reduction mechanism **94** by the rotation of the front wheel FW from a grounding part of the front wheel FW. A load F**2** denotes a load (compression force) exerted on the elastic member **200**. In addition, a position X**1** indicates a position in the up-and-down direction of the unsprung mass M**1** (an unsprung position) in the vibration reduction mechanism **94**. Further, a position X**2** indicates a position in the up-and-down direction of the sprung mass M**2** (a sprung position) in the vibration reduction mechanism **94**.

(18) The elastic member **200** is a member having a spring constant. A spring or rubber is used as the elastic member **200**, and a coil spring can be used in the present embodiment. In addition, the viscosity damping member **250** is of a mono-tube type, although its detailed illustration is omitted, and may include a magneto-rheological fluid (MRF) as the hydraulic oil. A piston rod is slidably inserted in an axial direction into a cylinder having a tubular shape in which the MRF is filled, and the inside of the cylinder is partitioned into an upper oil chamber and a lower oil chamber by a piston attached to a tip end of the piston rod. When an electric current is supplied to a coil located inside a communication passage that communicates the upper oil chamber with the lower oil chamber, a magnetic field is applied to the MRF, which flows in the communication passage, and ferromagnetic particles form clusters. This changes the viscosity of the MRF, which passes through the communication passage, so that the damping force of the viscosity damping member **250** can be changed. Note that the viscosity damping member **250** is not limited to a mechanism using the magneto-viscous fluid (MRF), and may also be a mechanism that changes the amount of oil (hydraulic oil) passing through an orifice by changing the diameter of the orifice with use of a step

motor or the like, so as to adjust the damping force.

(19) [Configuration of Control Device]

(20) FIG. **3** is a diagram illustrating a configuration example of a control device **300** according to the present embodiment. The control device **300** is a device that controls the suspension mechanism **9** of the vehicle **1**, and may include a sensor unit **310** and a processing unit **320**.

(21) The sensor unit **310** includes an inertial measurement unit (IMU: Internal Measurement Unit), which detects acceleration and an angular velocity generated in the vehicle **1**, and which is thus capable of detecting an attitude of the vehicle **1**. The inertial measurement unit is disposed at any appropriate position of the vehicle **1**, for example, in the vicinity of the center of gravity of the vehicle **1**. In the case of the present embodiment, in the sensor unit **310**, acceleration sensors **311** to **313**, each of which detects translational acceleration of the vehicle **1**, and angular velocity sensors **314** to **316**, each of which detects an angular velocity of the vehicle **1**, are provided as inertial measurement units. The X-axis acceleration sensor **311** detects translational acceleration in the front-and-rear direction (X-axis direction) of the vehicle **1**, the Y-axis acceleration sensor **312** detects translational acceleration in the vehicle width direction (Y-axis direction) of the vehicle **1**, and the Z-axis acceleration sensor **313** detects translational acceleration in the up-and-down direction (Z-axis direction) of the vehicle **1**. The X-axis angular velocity sensor **314** detects an angular velocity around X-axis, the Y-axis angular velocity sensor **315** detects an angular velocity around Y-axis, and the Z-axis angular velocity sensor **316** detects an angular velocity around Z-axis. In addition, the sensor unit **310** includes a vehicle speed sensor **317**, which detects the speed of the vehicle **1**, and a wheel speed sensor **318**, which detects the wheel speed of the vehicle **1**. The wheel speed sensor **318** in the present embodiment can be configured to be capable of detecting the wheel speed of the front wheel FW, but may be configured to be also capable of detecting the wheel speed of the rear wheel RW. Note that in the following, the translational acceleration in the vehicle width direction of the vehicle **1** detected by the Y-axis acceleration sensor **312** will be referred to as “lateral acceleration”, and the angular velocity in a yaw direction (a rotation direction around Z axis) of the vehicle **1** detected by the Z-axis angular velocity sensor **316** will be referred to as “a yaw angular velocity”, in some cases.

(22) The processing unit **320** is, for example, an electronic control unit (ECU), and may include a computer including a processor represented by a CPU, a storage device such as semiconductor memory, and an interface with external devices. The storage device (memory) of the processing unit **320** stores an application program (hereinafter, referred to as a control program, in some cases) for controlling the suspension mechanism **9** of the vehicle **1**, and the processor of the processing unit **320** can read and execute the control program stored in the storage device. Here, the control program includes a program for estimating the stroke speed of the suspension mechanism **9** of the vehicle **1**. In addition, the control program may be stored in a storage medium such as a CD-ROM, a DVD, or a memory to be installed in the processing unit **320** from the storage medium, or may be downloaded from an external server through a network to be installed in the processing unit **320**.

(23) In the case of the present embodiment, the processing unit **320** can include an estimation unit **321**, a correction unit **322**, a control unit **323**, and the correction unit **322**. The estimation unit **321** estimates the stroke speed of the suspension mechanism **9** of the vehicle **1**, based on detection results in the sensor unit **310**. The correction unit **322** corrects the stroke speed estimated by the estimation unit **321**. The control unit **323** controls the suspension mechanism **9**, based on the stroke speed corrected by the correction unit **322**. In the case of the present embodiment, from the viewpoint of improving the steering stability and the riding comfort of the vehicle **1**, the control unit **323** conducts so-called skyhook control for controlling the damping force of the vibration reduction mechanism **94** (the viscosity damping member **250**) by using the skyhook theory, which assumes that the vehicle **1** (the vehicle body and the like) is suspended in midair by a virtual line. Specifically, by supplying an electric current to a coil of the viscosity damping member **250** of the vibration reduction mechanism **94** to change the viscosity of the magnetic fluid inside the viscosity

damping member **250**, the control unit **323** is capable of controlling the damping force of the vibration reduction mechanism **94**, that is, conducting the skyhook control. In addition, in a case where a mechanism that changes the diameter of an orifice through which oil passes is used as the viscosity damping member **250**, the control unit **323** may change the diameter of the orifice of the viscosity damping member **250** to change the amount of oil that passes through the orifice, and may control the damping force of the vibration reduction mechanism **94**.

(24) Here, the tires of the straddle type vehicle **1** are not planar ones like the tires of a four-wheeled vehicle, and the tires each have a curved tread surface. For this reason, the circumferential length of the grounding part of the tire (the front wheel FW) of the straddle type vehicle **1** changes in accordance with turning of the straddle type vehicle **1**, and an error may occur in the stroke speed in accordance with a change in the circumferential length. That is, in the straddle type vehicle **1**, in a case where it is possible to obtain the stroke speed of the suspension mechanism **9** in a more accurate manner, there is room for further improving the steering stability and the riding comfort. For such a purpose, the correction unit **322** in the present embodiment corrects the stroke speed estimated by the estimation unit **321** in accordance with the circumferential length of the grounding part of the tire that changes in accordance with turning of the vehicle **1**.

(25) Hereinafter, estimation of the stroke speed by the control device **300** in the present embodiment will be described with reference to FIGS. **4** and **5**. FIG. **4** is a block diagram illustrating estimation of the stroke speed by the control device **300** in the present embodiment. FIG. **5** is a flowchart illustrating processing (that is, processing of generating a correction coefficient C) performed by the correction unit **322** of the control device **300**.

(26) First, processing of the estimation unit **321** will be described with reference to FIG. **4**. The estimation unit **321** includes a variation calculation unit **321***a*, a gain multiplication unit **321***b*, and a model calculation unit **321***c*, and estimates the stroke speed of the suspension mechanism **9** of the vehicle **1**, based on detection results in the sensor unit **310**.

(27) The variation calculation unit **321***a* calculates (outputs) a wheel speed variation ΔVw [rad/s] of the vehicle **1**, based on a wheel speed Vw [rad] of the vehicle **1** that has been detected by the wheel speed sensor **318**. For example, by using a bandpass filter, the variation calculation unit **321***a* passes frequency components in a specified band (for example, 0.5 Hz to 5 Hz) from a signal of the wheel speed Vw that has been detected by the wheel speed sensor **318**, and is thus capable of calculating the wheel speed variation ΔVw. In the present embodiment, the signal of the wheel speed Vw is input from the wheel speed sensor **318** at a cycle of approximately 10 msec to 20 msec. The bandpass filter has a low-pass characteristic of passing frequency components lower than 5 Hz in order to block high-frequency components from the signal and to reliably make available frequency components in a resonance band of the sprung mass M**2** (a signal in a frequency band corresponding to the vibration of the sprung mass M**2**). When the signal of the wheel speed Vw is input from the wheel speed sensor **318** at a shorter cycle, the bandpass filter may have a low-pass characteristic in a higher band, for example, 20 Hz so as to be also capable of extracting a frequency component in a resonance band of the unsprung mass M**1**. In addition, the bandpass filter has a high-pass characteristic that passes frequency components higher than 0.5 Hz to remove a DC component from the signal of the wheel speed Vw and to also remove a vehicle body speed component (a vehicle body speed component by braking and driving force) caused by an operation or the like by the driver.

(28) The gain multiplication unit **321***b* multiplies the wheel speed variation ΔVw, which has been calculated by the variation calculation unit **321***a*, by a coefficient (gain G) as expressed in the following Formula (1), and calculates (outputs) a grounding load variation ΔF [N]. The grounding load variation ΔF denotes a variation of the unsprung mass M**2**, and the gain G can be set beforehand by performing an experiment, a simulation, or the like, with use of the fact that the wheel speed variation ΔVw and a variation of the unsprung mass M**1** have a certain correlation, in a state in which the straddle type vehicle **1** is upright (not inclined). In addition, the coefficient C in

the following Formula (1) denotes a correction coefficient (correction value) to be multiplied by the gain G in order to correct the stroke speed estimated by the estimation unit **321**, and is generated by the correction unit **322** to be described later. In the following, the coefficient C will be referred to as a correction coefficient C, in some cases.

(29) $F = Vw \times G \times C$ (1)

(30) The model calculation unit **321***c* calculates (outputs) a stroke speed Ss of the suspension mechanism **9**, based on the grounding load variation ΔF, which has been calculated by the gain multiplication unit **321***b* in accordance with a predetermined model. The predetermined model serves as a model in which input is set with the grounding load variation ΔF, which has been calculated by the gain multiplication unit **321***b*, and output is set with the stroke speed of the suspension mechanism **9**, and the model can be generated beforehand in an experiment, a simulation, or the like. As an example of the predetermined model, it is possible to refer to Patent Literature 1 described above.

(31) Next, processing of the correction unit **322** will be described with reference to FIGS. **4** and **5**. The correction unit **322** includes a determination unit **322***a* and a generation unit **322***b*, and corrects the stroke speed estimated by the estimation unit **321** in accordance with the circumferential length of the grounding part of the tire (the front wheel FW) changed by turning of the vehicle **1**. The determination unit **322***a* determines a circumferential length L of the grounding part of the tire that changes in accordance with turning of vehicle **1**, based on detection results in the sensor unit **310** (for example, lateral acceleration a, which has been detected by the Y-axis acceleration sensor **312**, a yaw angular velocity @, which has been detected by the Z-axis angular velocity sensor **316**, and the vehicle speed V, which has been detected by vehicle speed sensor **317**). The generation unit **322***b* generates a correction coefficient C (correction value) for correcting the stroke speed estimated by the estimation unit **321**, based on the circumferential length L, which has been determined by the determination unit **322***a*. The correction coefficient C, which has been generated by the generation unit **322***b*, is multiplied by the gain G in order to correct the gain G of the gain multiplication unit **321***b*. Hereinafter, the processing of the correction unit **322** will be specifically described along the flowchart illustrated in FIG. **5**.

(32) In step S**11**, the correction unit **322** (the determination unit **322***a*) acquires detection results in the sensor unit **310**. In the case of the present embodiment, the determination unit **322***a* acquires the acceleration in the vehicle width direction of the vehicle **1** that has been detected by the Y-axis acceleration sensor **312** and the speed of the vehicle **1** (the vehicle speed) that has been detected by the vehicle speed sensor **317**, as the detection results in the sensor unit **310**.

(33) In step S**12**, the correction unit **322** (the determination unit **322***a*) calculates a roll angle of the vehicle **1**, based on the acceleration in the vehicle width direction of the vehicle **1** that has been detected by the Y-axis acceleration sensor **312**. For example, the determination unit **322***a* has information (hereinafter, referred to as roll angle information, in some cases) indicating a correspondence relationship between the acceleration in the vehicle width direction of the vehicle **1** and the roll angle of the vehicle **1**, and is capable of obtaining the roll angle of the vehicle **1** from the acceleration in the vehicle width direction of the vehicle **1** that has been detected by the Y-axis acceleration sensor **312**, based on the roll angle information. Note that the roll angle information is created beforehand in an experiment, a simulation, or the like, and is stored, as a table or a function, in the storage device of the processing unit **320**.

(34) In step S**13**, the correction unit **322** (the determination unit **322***a*) obtains a turning radius of the vehicle **1**, based on an angular velocity (a yaw angular velocity) in the yaw direction of the vehicle **1** that has been detected by the Z-axis angular velocity sensor **316** and the vehicle speed of the vehicle **1** that has been detected by the vehicle speed sensor **317**, and calculates a rudder angle (a steering angle) of the vehicle **1**.

(35) Here, a method for calculating the turning radius of the vehicle **1** will be described. In each

formula to be described below, "V" denotes the vehicle speed [m/s], which has been detected by the vehicle speed sensor **317**. "@" denotes the yaw angular velocity [rad/s], which has been detected by the Z-axis acceleration sensor **316**. In addition, "R" denotes the turning radius [m] of the vehicle **1**, and "m" denotes the weight of the vehicle **1**. The weight of the vehicle **1** is known information, and is stored beforehand in the storage device of the processing unit **320**.
(36) The angular velocity @ can be expressed by (vehicle speed V/turning radius R), and thus the turning radius R can be expressed by Formula (2). Therefore, by using Formula (2), the determination unit **322***a* is capable of obtaining the turning radius R of the vehicle **1**, based on the yaw angular velocity ω, which has been detected by the Z-axis acceleration sensor **316**, and the vehicle speed V, which has been detected by vehicle speed sensor **317**.
(37) $V = R$ (2) $R = V /$
(38) In addition, the determination unit **322***a* has information (hereinafter, referred to as rudder angle information, in some cases) indicating a correspondence relationship among the turning radius R, the roll angle, and the rudder angle, and is capable of obtaining the rudder angle of the vehicle **1** from the turning radius R, which has been obtained as described above, and the roll angle obtained in step S**12**, based on the steering angle information. Note that the rudder angle information is created beforehand in an experiment, a simulation, or the like, and is stored, as a table or a function (matrix), in the storage device of the processing unit **320**.
(39) In step S**14**, the correction unit **322** (the determination unit **322***a*) calculates a camber angle of the front wheel FW of the vehicle **1**, based on the roll angle calculated in step S**12** and the rudder angle calculated in step S**13**. For example, by using the following Formula (3), the determination unit **322***a* is capable of obtaining the camber angle of the front wheel FW. In Formula (3), "θ.sub.Rf" denotes the camber angle [rad] of the front wheel FW, "B" denotes the caster angle [rad] of the vehicle **1**, "OR" denotes the roll angle [rad], and "On" denotes the rudder angle [rad]. The caster angle is defined as an angle formed by the front forks **95** and the ground (a horizontal plane), and is stored beforehand, as known information, in the storage device.
(40) $_{Rf} = \sin^{-1}(\sin$ .Math. $\cos\ _{R}$ .Math. $\sin\ _{H} + \sin\ _{R}$ .Math. $\cos\ _{H})$ (3)
(41) In step S**15**, the correction unit **322** (the determination unit **322***a*) determines the circumferential length L of the grounding part of the tire of the front wheel FW, based on the camber angle θ.sub.Rf calculated in step S**14**. For example, the determination unit **322***a* has information (hereinafter, referred to as circumferential length information, in some cases) indicating a correspondence relationship between the camber angle θ.sub.Rf and the circumferential length L, and is capable of obtaining the circumferential length L from the camber angle θ.sub.Rf calculated in step S**14**, based on the circumferential length information. The circumferential length information is acquired beforehand by measuring the circumferential length L, while changing the camber angle θ.sub.Rf, in a state in which the tire of the front wheel FW is pressed against the ground with a constant load, and is stored, as a table or a function, in the storage device of the processing unit **320**.
(42) In step S**16**, the correction unit **322** (the generation unit **322***b*) determines a correction coefficient C, based on the circumferential length L determined in step S**15**. For example, by using the following Formula (4), the generation unit **322***b* is capable of obtaining the correction coefficient C. In Formula (4), "L.sub.base" denotes the circumferential length of the grounding part of the tire (the front wheel FW), in a state in which the vehicle **1** is upright, that is, the maximum circumferential length of the tire. The correction coefficient C generated in step S**16** is multiplied by the gain G of the gain multiplication unit **321***b*, as expressed in the above Formula (1).
(43) $C = L_{base} / L$ (4)
(44) In step S**17**, the correction unit **322** determines whether to end the processing. For example, the correction unit **322** is capable of determining to end the processing, when the ignition is turned off by the user (driver). In a case where the correction unit **322** determines not to end the

processing, the processing returns to step S**11** and repeats steps S**11** to S**16**.
(45) As described above, the control device **300** (the estimation device) in the present embodiment corrects the stroke speed of the suspension mechanism **9**, which is estimated, based on the detection results in the sensor unit **310**, in accordance with the circumferential length of the grounding part of the tire to be changed by turning of the vehicle **1**. This enables the stroke speed of the suspension mechanism **9** of the straddle type vehicle **1** to be accurately obtained, and enables further improvement in the steering stability and the riding comfort of the vehicle **1**. In addition, according to the configuration of the vehicle **1** in the present embodiment, it becomes possible to accurately obtain the stroke speed of the suspension mechanism **9** without provision of a sensor that detects the stroke speed, so that such a sensor can be eliminated, and it can be advantageous in terms of the vehicle cost. Here, in the above embodiment, an example of estimating the stroke speed of the suspension mechanism **9**, which is provided for the front wheel FW, has been described. However, it is possible to estimate the stroke speed similarly in the suspension mechanism **9**, which is provided for the rear wheel RW.
SUMMARY OF EMBODIMENTS
(46) 1. A control device of the above-described embodiments is a control device (e.g. **300**) that controls a suspension mechanism (e.g. **9**) of a straddle type vehicle (e.g. **1**), comprising: a wheel speed sensor (e.g. **318**) that detects a wheel speed of the straddle type vehicle; estimation means (e.g. **321**) for estimating a stroke speed of the suspension mechanism, based on a change in the wheel speed detected by the wheel speed sensor; and correction means (e.g. **322**) for correcting the stroke speed estimated by the estimation means, in accordance with a circumferential length of a grounding part of a tire changed by turning of the straddle type vehicle.
(47) According to this embodiment, it becomes possible to accurately obtain the stroke speed of the suspension mechanism of the straddle type vehicle, so that the steering stability and the riding comfort of the vehicle can be further improved. In addition, it becomes possible to accurately obtain the stroke speed without provision of a sensor that detects the stroke speed of the suspension mechanism, so that the sensor can be reduced, and it can be advantageous in terms of the vehicle cost.
(48) 2. In the above-described embodiments, the estimation means estimates the stroke speed, based on a value obtained by multiplying the change in the wheel speed detected by the wheel speed sensor by a gain (e.g. G), and the correction means corrects the stroke speed by correcting the gain in accordance with the circumferential length.
(49) According to this embodiment, it becomes possible to appropriately correct the stroke speed of the suspension mechanism, so that the stroke speed can be accurately obtained.
(50) 3. In the above-described embodiments, the vehicle control device further comprises an acceleration sensor (e.g. **312**) that detects acceleration in a vehicle width direction generated in the straddle type vehicle, wherein the correction means includes: determination means (e.g. **322***a*) for calculating a roll angle of the straddle type vehicle based on the acceleration detected by the acceleration sensor, and also determining the circumferential length based on the roll angle; and generation means (e.g. **322***b*) for generating a correction value (e.g. C) for correcting the stroke speed, based on the circumferential length determined by the determination means.
(51) According to this embodiment, it becomes possible to appropriately generate the correction value for correcting the stroke speed of the suspension mechanism.
(52) 4. In the above-described embodiments, the vehicle control device further comprises a vehicle speed sensor (e.g. **317**) that detects a vehicle speed of the straddle type vehicle; and an angular velocity sensor (e.g. **316**) that detects an angular velocity in a yaw direction of the straddle type vehicle, wherein the determination means further calculates a rudder angle of the straddle type vehicle based on the angular velocity detected by the angular velocity sensor and the vehicle speed detected by the vehicle speed sensor, also calculates a camber angle of a wheel of the straddle type vehicle based on the rudder angle and the roll angle, and determines the circumferential length

based on the camber angle.
(53) According to this embodiment, it becomes possible to appropriately generate the correction value for correcting the stroke speed of the suspension mechanism.
(54) 5. In the above-described embodiments, the determination means determines the circumferential length from the camber angle, based on information indicating a relationship between the camber angle and the circumferential length.
(55) According to this embodiment, it becomes possible to appropriately generate the correction value for correcting the stroke speed of the suspension mechanism.
(56) 6. In the above-described embodiments, the information is acquired by measuring the circumferential length while changing the camber angle in a state in which the tire is pressed against ground with a constant load.
(57) According to this embodiment, it becomes possible to appropriately acquire the information indicating the relationship between the camber angle and the circumferential length, so that the correction value can be accurately generated, based on the information.
(58) 7. In the above-described embodiments, the control device further comprises control means (e.g. **323**) for controlling the suspension mechanism based on the stroke speed corrected by the correction means.
(59) According to this embodiment, it becomes possible to control the suspension mechanism, based on the corrected stroke speed, so that steering stability and riding comfort of the vehicle can be further improved.
(60) 8. In the above-described embodiments, the control means conducts sky-hook control of the straddle type vehicle based on the stroke speed corrected by the correction means.
(61) According to this embodiment, by controlling the suspension mechanism as the skyhook control, based on the corrected stroke speed, the steering stability and the riding comfort of the vehicle can be further improved.
(62) While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

Claims

1. A control device that controls a suspension mechanism of a straddled vehicle, comprising: a wheel speed sensor configured to detect a wheel speed of the straddled vehicle; an estimation unit configured to estimate a stroke speed of the suspension mechanism, based on a change in the wheel speed detected by the wheel speed sensor; and a correction unit configured to correct the stroke speed estimated by the estimation unit, in accordance with a circumferential length of a grounding part of a tire changed by turning of the straddled vehicle.
2. The control device according to claim 1, wherein the estimation unit is configured to estimate the stroke speed, based on a value obtained by multiplying the change in the wheel speed detected by the wheel speed sensor by a gain, and the correction unit is configured to correct the stroke speed by correcting the gain in accordance with the circumferential length.
3. The vehicle control device according to claim 1, further comprising an acceleration sensor configured to detect acceleration in a vehicle width direction generated in the straddled vehicle, wherein the correction unit is configured to: calculate a roll angle of the straddled vehicle based on the acceleration detected by the acceleration sensor, and determine the circumferential length based on the roll angle; and generate a correction value for correcting the stroke speed, based on the determined circumferential length.
4. The control device according to claim 3, further comprising: a vehicle speed sensor configured to detect a vehicle speed of the straddled vehicle; and an angular velocity sensor configured to

detect an angular velocity in a yaw direction of the straddled vehicle, wherein the determination unit is configured to further calculate a rudder angle of the straddled vehicle based on the angular velocity detected by the angular velocity sensor and the vehicle speed detected by the vehicle speed sensor, calculate a camber angle of a wheel of the straddled vehicle based on the rudder angle and the roll angle, and determine the circumferential length based on the camber angle.

5. The control device according to claim 4, wherein the determination unit is configured to determine the circumferential length from the camber angle, based on information indicating a relationship between the camber angle and the circumferential length.

6. The control device according to claim 5, wherein the information is acquired by measuring the circumferential length while changing the camber angle in a state in which the tire is pressed against ground with a constant load.

7. The control device according to claim 1, further comprising a control unit configured to control the suspension mechanism based on the stroke speed corrected by the correction unit.

8. The control device according to claim 7, wherein the control unit is configured to conduct sky-hook control of the straddled vehicle based on the stroke speed corrected by the correction unit.

9. A vehicle comprising a control device according to claim 1.

10. An estimation method for estimating a stroke speed of a suspension mechanism of a straddled vehicle, comprising: detecting a wheel speed of the straddled vehicle; estimating the stroke speed, based on a change in the detected wheel speed; and correcting the estimated stroke speed, in accordance with a circumferential length of a grounding part of a tire changed by turning of the straddled vehicle.

11. A non-transitory computer-readable storage medium storing a program for causing a computer to perform an estimation method according to claim 10.