

US Patent & Trademark Office

Patent Public Search | Text View

United States Patent	12392109
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Fujio; Kazuhiro

Work machine

Abstract

A work machine includes a work unit, a main body, a detection unit, and a controller. The work unit executes work. The main body supports the work unit. The detection unit detects a posture of the main body. The controller executes a restriction process of restricting at least one of a motion of the work unit and a motion of the main body based on a detection result of the detection unit.

Inventors:	Fujio; Kazuhiro (Fukuoka, JP)
Applicant:	Yanmar Holdings Co., Ltd. (Osaka, JP)
Family ID:	1000008767873
Assignee:	Yanmar Holdings Co., Ltd. (Osaka, JP)
Appl. No.:	17/835955
Filed:	June 08, 2022

Prior Publication Data

Document Identifier	Publication Date
US 20220396932 A1	Dec. 15, 2022

Foreign Application Priority Data

JP	2021-098701	Jun. 14, 2021
----	-------------	---------------

Publication Classification

Int. Cl.: E02F9/22 (20060101); E02F9/20 (20060101); E02F9/24 (20060101); E02F9/26 (20060101)

U.S. Cl.:

CPC **E02F9/2033** (20130101); **E02F9/24** (20130101); **E02F9/26** (20130101); E02F9/2228 (20130101); E02F9/2285 (20130101); E02F9/2292 (20130101)

Field of Classification Search

CPC: E02F (3/964); E02F (9/262); E02F (9/2033); E02F (9/26); E02F (9/24); E02F (9/265); E02F (9/2246); E02F (9/2292); E02F (9/2228); E02F (9/2285)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2009/0318263	12/2008	Yuet	701/99	B60T 7/16
2011/0125376	12/2010	Chappell	701/65	B60W 10/06
2014/0121840	12/2013	Mizuochi	700/275	G06F 30/15
2017/0130429	12/2016	Lafrenier	N/A	B60Q 5/005
2019/0017248	12/2018	Okada	N/A	E02F 9/20
2019/0234048	12/2018	Zhou	N/A	E02F 9/26
2020/0315083	12/2019	Mei	N/A	A01B 69/00
2021/0025135	12/2020	Sakuta	N/A	E02F 9/2253

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
3779062	12/2020	EP	N/A
2013151830	12/2012	JP	N/A
2020159142	12/2019	JP	N/A
WO-2019189031	12/2018	WO	E02F 9/128

Primary Examiner: Holwerda; Stephen

Background/Summary

CROSS-REFERENCE

(1) This application claims foreign priority of IP2021-098701 filed Jun. 14, 2021, the disclosure of which is hereby incorporated by reference in its entirety

TECHNICAL FIELD

(2) The present disclosure relates to a work machine.

BACKGROUND ART

(3) The hydraulic excavator described in Patent Document 1 includes a safety device against overturning. The safety device against overturning calculates the center of gravity of the hydraulic excavator. The safety device against overturning calculates a center-of-gravity safety zone. The safety device against overturning outputs a warning when the center of gravity approaches a boundary of the center-of-gravity safety zone.

PRIOR ART DOCUMENT

Patent Document

(4) Patent Document 1: Japanese Unexamined Patent Application Publication No. 7-207711

SUMMARY OF INVENTION

Technical Problem

(5) However, the work machine, such as the hydraulic excavator, described in Patent Document 1 does not restrict a motion of the work machine located on an inclined surface, and therefore, tipping-over of the work machine caused by a motion of the work machine may not be avoided.

(6) The present disclosure is made in view of the above-mentioned problem, and it is an object to provide a work machine that can be restrained from tipping-over caused by a motion of the work machine in an inclined state.

Solution to Problem

(7) According to an aspect of the disclosure, a work machine includes a work unit, a main body, a detection unit, and a controller. The work unit performs works. The main body supports the work unit. The detection unit detects a posture of the main body. The controller executes a restriction process of restricting at least one of a motion of the work unit and a motion of the main body based on a detection result of the detection unit.

Advantageous Effects of Invention

(8) According to the work machine of the present disclosure, the work machine can be prevented from tipping-over caused by a motion of the work machine in an inclined state.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. 1 is a diagram illustrating a work machine according to an embodiment of the present disclosure.

(2) FIG. 2 is a block diagram illustrating a hydraulic configuration and an electrical configuration of the work machine according to the embodiment.

(3) FIG. 3 is a diagram illustrating an example of a process executed by a controller of the work machine according to the embodiment.

(4) FIG. 4 is a diagram illustrating the work machine according to the embodiment.

(5) FIG. 5A is a diagram illustrating the work machine located in an inclined surface. FIG. 5B is a plan view of the work machine of FIG. 5A.

(6) FIG. 6A is a diagram illustrating the work machine located in an inclined surface. FIG. 6B is a plan view of the work machine of FIG. 6A.

(7) FIG. 7A is a diagram illustrating the work machine located in an inclined surface. FIG. 7B is a plan view of the work machine of FIG. 7A.

(8) FIG. 8 is a diagram illustrating a pattern table of a swivel body of the work machine according to the embodiment.

(9) FIG. 9A is a diagram illustrating the work machine located in an inclined surface. FIG. 9B is a plan view of the work machine of FIG. 9A in a first posture. FIG. 9C is a plan view of the work machine of FIG. 9A in a second posture.

(10) FIG. 10A is a diagram illustrating the work machine located in an inclined surface. FIG. 10B is a plan view of the work machine of FIG. 10A in a third posture. FIG. 10C is a plan view of the work machine of FIG. 10A in a fourth posture.

(11) FIG. 11 is a diagram illustrating a pattern table of a work unit of the work machine according to the embodiment.

(12) FIG. 12 is a diagram illustrating an image displayed on a display unit of a reporting unit of the work machine according to the embodiment.

(13) FIG. 13 is a flowchart of a process executed by a controller of the work machine according to the embodiment.

DESCRIPTION OF EMBODIMENTS

(14) An embodiment of the present disclosure will be described hereinafter with reference to the

accompanying drawings. Note that the present disclosure is not limited to the embodiment below. The explanation may be omitted where the explanation is duplicated as appropriate. Furthermore, in the drawings, the same reference signs are used for the same or equivalent components, and redundant descriptions are omitted.

First Embodiment

(15) Referring to FIG. 1, a work machine 1 according to an embodiment of the present disclosure will be described. The work machine 1 includes construction machinery and agricultural machinery, for example, and may be self-propelled or stationary machinery. The following is an example of this embodiment where the work machine 1 is a hydraulic excavator. A hydraulic excavator is an example of construction machinery.

(16) FIG. 1 is a diagram illustrating a work machine 1 according to this embodiment. As illustrated in FIG. 1, the work machine 1 of this embodiment includes a main body 2, a work unit 3, and an engine unit 6. The main body 2 supports the work unit 3. The main body 2 includes a swivel body 4 and a traveling body 5.

(17) The swivel body 4 is supported by the traveling body 5. Specifically, the swivel body 4 is positioned over the traveling body 5, for example, via a swivel bearing. The swivel body 4 is supported by the traveling body 5 in a swivelable manner.

(18) The swivel body 4 includes a cabin 43 and a swivel motor 40. The engine unit 6 is included in the swivel body 4.

(19) The cabin 43 accommodates a driver's seat 401 and an operating unit 20. An operator sits on the driver's seat 401. In this specification, a left side viewed from the operator seated on the driver's seat 401 may be described as a left direction. Similarly, a right side viewed from the operator seated on the driver's seat 401 may be described as a right direction. A front side viewed from the operator seated on the driver's seat 401 may be described as a front direction. A rear side viewed from the operator seated on the driver's seat 401 may be described as a rear direction.

(20) The operating unit 20 can individually operate the work unit 3, the swivel body 4, and the traveling body 5. The operator seated on the driver's seat 401 operates the operating unit 20 so as to individually control the work unit 3, the swivel body 4, and the traveling body 5. The operating unit 20 includes a traveling lever (not shown) that operates the traveling body 5. The traveling lever can cause the traveling body 5 to travel irrespective of a swivel angle of the swivel body 4, and in FIG. 1, when the traveling lever is tilted toward the front of the machine (to the left in the drawing), the work machine 1 travels in the left direction in the drawing. Furthermore, in a case where the swivel body 4 swivels 180° and faces the right side in the drawing, when the traveling lever is tilted toward the front of the machine (to the right in the drawing), the machine travels in the left direction in the drawing.

(21) The swivel motor 40 swivels the cabin 43. Specifically, the swivel motor 40 swivels the cabin 43 via the swivel bearing. The swivel motor 40 is, for example, a hydraulic motor. The swivel motor 40, for example, swivels the cabin 43 in the left direction or the right direction relative to the traveling body 5 in response to an operation performed on the operating unit 20.

(22) The traveling body 5 causes the work machine 1 to travel. Specifically, for example, the traveling body 5 is driven by pressure oil discharged by a hydraulic pump 7 (main pump 71) powered by the engine unit 6, and causes the work machine 1 to travel in accordance with an operation performed on the operating unit 20. In this embodiment, the traveling body 5 is a crawler-type traveling device. Specifically, the traveling body 5 includes a traveling motor 50 and a crawler 501. Note that the pressure oil is the hydraulic oil to which high pressure is applied to operate a hydraulic actuator described below.

(23) The crawler 501 is a pair of crawlers 501. The pair of crawlers 501 includes a first crawler 501A and a second crawler 501B. The first crawler 501A is disposed in the left direction. The second crawler 501B is disposed in the right direction.

(24) The traveling motor 50 rotates and drives the crawler 501. The traveling motor 50 is, for

example, a hydraulic motor. The traveling motor **50** is a pair of traveling motors **50**. The pair of traveling motors **50** includes a first traveling motor and a second traveling motor. The first traveling motor rotates and drives the first crawler **501A**. The second traveling motor rotates and drives the second crawler **501B**.

(25) The traveling body **5** further includes a blade **511**, a blade cylinder **512**, and a blade arm **513**. The blade **511** has a soil removal mechanism and is used for a ground leveling operation and other operations. The blade **511** has a plate shape. The blade cylinder **512** drives the blade **511**. The blade arm **513** supports the blade **511**.

(26) The work unit **3** execute work. Specifically, for example, the work unit **3** is driven by power supplied from the engine unit **6** and performs soil excavation work in response to an operation of the operating unit **20**. In this embodiment, the work unit **3** includes a boom **301**, an arm **302**, a bucket **303**, a boom cylinder **31**, an arm cylinder **32**, and a bucket cylinder **33**.

(27) The boom **301** is supported by the swivel body **4** to swing with a first rotation supporting point **R1** at a center.

(28) The boom cylinder **31** actuates the boom **301**. Specifically, the boom cylinder **31** is driven by hydraulic fluid to cause the boom **301** to be swung with the first rotation supporting point **R1** at the center. The boom cylinder **31** includes a cylinder body, a piston that divides an internal space of the cylinder body into two hydraulic chambers, and a rod that is connected to the piston at one end and outputs hydraulic power. The piston is moved forward and backward inside the cylinder body by the hydraulic fluid, and the rod actuates the boom **301**.

(29) The arm **302** is supported by the boom **301** to swing with a second rotation supporting point **R2** at a center.

(30) An arm cylinder **32** actuates the arm **302**. Specifically, the arm cylinder **32** is driven by the hydraulic fluid and causes the arm **302** to be swung with the second rotation supporting point **R2** at the center. The arm cylinder **32** has the same configuration as the boom cylinder **31** described above.

(31) The bucket **303** is a type of attachment. The bucket **303** is supported by the arm **302** to swing via a bucket link (not shown) at an end of the arm **302** with a third rotation supporting point **R3** at a center. Furthermore, a crane hook (not shown) for a suspending operation is attached to the bucket link.

(32) A bucket cylinder **33** actuates the bucket **303**. Specifically, the bucket cylinder **33** is driven by the hydraulic fluid and causes the bucket **303** to be swung with the third rotation supporting point **R3** at the center. The bucket cylinder **33** has the same configuration as the boom cylinder **31** described above.

(33) The engine unit **6** drives a hydraulic pump **7** (main pump **71**) described below to dispense pressure oil so as to drive the boom cylinder **31**, the arm cylinder **32**, the bucket cylinder **33**, the swivel motor **40**, the first traveling motor, and the second traveling motor. Note that the boom cylinder **31**, the arm cylinder **32**, the bucket cylinder **33**, the swivel motor **40**, the first traveling motor, and the second traveling motor may be collectively referred to as hydraulic actuators where appropriate hereinafter.

(34) In the work machine **1** having the above-described configuration, the traveling body **5** travels by rotation drive of the traveling motor **50**, and the swivel body **4** swivels by swivel drive of the swivel motor **40**. Furthermore, the bucket **303** moves upward, downward, forward, and backward by extension and retraction of the boom cylinder **31** and the arm cylinder **32**, and the bucket **303** performs a dump operation or a cloud operation by extension and retraction of the bucket cylinder **33**.

(35) Referring to FIGS. **1** and **2**, operation of the work machine **1** will be described in more detail. FIG. **2** is a block diagram illustrating a hydraulic configuration and an electrical configuration of the work machine **1**.

(36) As shown in FIG. **2**, the work machine **1** includes the engine unit **6** described above, the

hydraulic pump 7 (main pump 71 and pilot pump 72), a control valve 8, a solenoid valve 9, a hydraulic oil tank 10, a controller 11, and detection units 12 to 18.

(37) As illustrated in FIG. 1, the engine unit 6 of the work machine 1 of this embodiment includes an engine 61 and an engine controller 62. The engine controller 62 is an ECU (Engine Control Unit), for example. Fuel is supplied from a fuel tank (not shown) to the engine 61.

(38) The engine 61 drives the hydraulic pump 7 (main pump 71 and pilot pump 72). As a result, the hydraulic pump 7 (main pump 71) discharges pressure oil from the hydraulic oil tank 10 and supplies the pressure oil to the control valve 8. The control valve 8 is used to supply the pressure oil to individual hydraulic actuators 31, 32, 33, 40, and 50. Consequently, the boom cylinder 31, the arm cylinder 32, the bucket cylinder 33, the swivel motor 40, the traveling motor 50 (first traveling motor and second traveling motor) are driven.

(39) The hydraulic pump 7 (pilot pump 72) discharges pilot oil from the hydraulic oil tank 10 and supplies the pilot oil to the solenoid valve 9. The solenoid valve 9 outputs the pilot oil to a control port of the control valve 8 in accordance with an operation performed on the operating unit 20 connected via the controller 11. As a result, the control valve 8 supplies pressure oil in which a direction and a flow rate thereof are controlled in accordance with the pilot oil to the individual hydraulic actuators 31, 32, 33, 40, and 50.

(40) The work machine 1 further includes the first detection unit 12, the second detection unit 13, the third detection unit 14, the fourth detection unit 15, the fifth detection unit 16, the sixth detection unit 17, and the seventh detection unit 18. The detection units 12 to 18 are individually connected to the controller 11.

(41) The first detection unit 12 detects a posture of the main body 2. The first detection unit 12 corresponds to an example of a “detection unit” of the present disclosure. The posture of the main body 2 indicates an inclination of the main body 2 and a direction of the main body 2 relative to an inclined surface. The inclination of the main body 2 indicates an angle of a surface where the main body 2 is located and a tilt of the main body 2 in accordance with the angle of the surface where the main body 2 is located, for example. Specifically, when the main body 2 is located on an inclined surface, a posture of the main body 2 is obtained in accordance with an angle of the inclined surface. The first detection unit 12 is mounted on the swivel body 4. The first detection unit 12 may be, for example, an inclination sensor, a rotation angle sensor, or a capacitance sensor. The first detection unit 12 may be an IMU (inertial measurement unit). The inertial measurement unit measures a roll angle of the main body 2 and a pitch angle of the main body 2. The first detection unit 12 outputs a detection result to the controller 11.

(42) The second detection unit 13 includes an angle sensor, for example, to detect an angle of the boom 301. The second detection unit 13 detects the angle of rotation of the boom 301. The second detection unit 13 is, for example, a potentiometer or a rotary encoder. The second detection unit 13 outputs a detection result to the controller 11.

(43) The third detection unit 14 includes an angle sensor, for example, to detect an angle of the arm 302. The third detection unit 14 detects an angle of rotation of the arm 302. The third detection unit 14 is, for example, a potentiometer or a rotary encoder. The third detection unit 14 outputs a detection result to the controller 11.

(44) The fourth detection unit 15 includes an angle sensor, for example, to detect an angle of the bucket 303. The fourth detection unit 15 detects an angle of rotation of the bucket 303. The fourth detection unit 15 is, for example, a potentiometer or a rotary encoder. The fourth detection unit 15 outputs a detection result to the controller 11.

(45) The fifth detection unit 16 acquires swivel angle information of the swivel body 4. The fifth detection unit 16 can detect a swivel angle of the swivel body 4 relative to the traveling body 5. The fifth detection unit 16 is, for example, a potentiometer or a rotary encoder. The fifth detection unit 16 is mounted, for example, on the swivel bearing not illustrated. The fifth detection unit 16 outputs a detection result to the controller 11.

(46) The sixth detection unit **17** is attached to the boom cylinder **31** and detects pressure of the hydraulic oil supplied to the boom cylinder **31**. The sixth detection unit **17** outputs a detection result to the controller **11**.

(47) The controller **11** can calculate a load of an excavated object accommodated in the bucket **303** based on the pressure of the hydraulic fluid detected by the sixth detection unit **17**. Furthermore, the controller **11** can calculate a load of an object suspended on the crane hook based on the pressure of the hydraulic fluid detected by the sixth detection unit **17**. Note that, in a description below, the load of the accommodated object in the bucket **303** and the load of the object suspended on the crane hook are collectively referred to as a “suspended load” where appropriate.

(48) The seventh detection unit **18** detects a state of environment surrounding the work machine **1**. The seventh detection unit **18** is, for example, a measurement range sensor, such as a TOF (Time Of Flight) camera. The TOF camera is, for example, a lidar. Specifically, the seventh detection unit **18**, for example, emits light around the work machine **1** and receives reflection light. The seventh detection unit **18** then outputs a signal corresponding to the received reflection light as a detection result to the controller **11**. That is, the seventh detection unit **18** outputs a signal indicating a state of the environment surrounding the work machine **1** to the controller **11**. The seventh detection unit **18** may be a millimeter wave radar, a camera, or a stereo camera, for example.

(49) Furthermore, as shown in FIG. 2, the work machine **1** further includes a reporting unit **19**, the controller **11**, and a storage unit **21**.

(50) The reporting unit **19** reports information indicating a state of the work machine **1** (hereinafter referred to as “state information” where appropriate) to the operator. The information reported by the reporting unit **19** includes, for example, a posture (inclination angle) of the main body **2**, a suspended load, a posture of the work unit **3**, a traveling speed of the work machine **1**, a degree of risk of tipping-over of the work machine **1**, and a warning (including content of control to prevent tipping-over). The warning includes restriction and prohibition a motion of the work machine **1**. The reporting unit **19** includes at least one visual reporting unit and one auditory reporting unit. The visual reporting unit includes, for example, a light-emitting unit and a display unit. The light-emitting unit is, for example, an LED (Light Emitting Diode) that reports state information by emitting light. For example, the light-emitting unit indicates a state of the work machine **1** by a light-emitting color or a light-emitting method. Specifically, when the state of the work machine **1** (tipping-over risk) is indicated by a light-emitting color, green indicates no tipping-over risk (safe state), yellow indicates low tipping-over risk (caution state), and red indicates high tipping-over risk (warning state). On the other hand, when the state of the work machine **1** (tipping-over risk) is indicated by a light-emitting method, light is turned off when there is no tipping-over risk (safe state, light is turned on when tipping-over risk is low (caution state), and light blinks when tipping-over risk is high (warning state). The display unit is composed of a display, such as a liquid crystal display or an organic EL display, and reports state information by displaying a message or an icon indicating the state of the work machine **1**. The auditory reporting unit is, for example, a speaker. The speaker reports a state of the work machine **1** by outputting a voice message or sound (including an alarm).

(51) The storage unit **21** includes a storage device and stores data and computer programs. Specifically, the storage unit **21** includes a main storage device, such as a semiconductor memory, and an auxiliary memory device, such as a semiconductor memory, a solid state drive, and/or a hard disk drive. The storage unit **21** may include a removable medium.

(52) The controller **11** controls the work machine **1**. The controller **11** includes a processor, such as an integrated ECU (Electronic Control Unit). The processor of the controller **11** controls the work machine **1** by executing the computer programs stored in the storage unit **21**.

(53) Determination Process

(54) Referring now to FIGS. 1 to 3, a determination process, performed by the controller **11**, of determining a posture of the work machine **1** based on a detection result of the first detection unit

12 will be described. FIG. 3 is a diagram illustrating an example of a process executed by the controller **11** of the work machine **1** according to the embodiment. When obtaining a detection result from the first detection unit **12**, the controller **11** determines a posture of the work machine **1** (posture of the main body **2**: inclined state) with reference to a determination condition stored in the storage unit **21**. For example, in a case where the determination condition indicates a risk of tipping-over in an inclination of 10° or more, when a detection result of the first detection unit **12** is 12° , the controller **11** determines that the work machine **1** has a risk of tipping-over in the posture thereof.

(55) The determination process can detect a posture of the work machine **1** at a certain temporary point or a temporal change in a posture of the work machine **1**. For example, the determination process can detect a change in a posture of the work machine **1** during traveling, or a change in a posture in accordance with a change in an environment where the work machine **1** is located. The change in the environment where the work machine **1** is located means, for example, a mechanical change in an inclination of a pedestal that supports the work machine **1**.

(56) Furthermore, when a change in a posture during traveling of the work machine **1** is detected, the detected posture of the main body **2** maintained for a predetermined period of time may be added to the determination condition. Specifically, for example, when the work machine **1** enters an inclined surface from a level surface by a traveling motion, an angle of the inclined surface is detected as a posture of the main body **2** for a period of traveling on the inclined surface, so that a change in a posture is detected using a posture of the work machine **1** in the level surface and a posture of the work machine **1** in the inclined surface. On the other hand, when the work machine **1** travels on an uneven road surface, a posture of the work machine **1** frequently changes according to the uneven surface, and therefore, the controller **11** does not detect a change in the posture of the work machine **1**. As a result, a restriction process caused by false detection can be prevented from being performed.

(57) Note that, in the determination process, determinations can be performed in stages by setting different determination conditions of different degrees. For example, a first determination condition with a relatively low risk of tipping-over and a second determination condition with a relatively high risk of tipping-over may be set. Specifically, the first determination condition includes an angle of the main body **2** indicated by a posture of the main body **2** that is equal to or larger than a first threshold value. In this case, an inclination angle for the first determination condition is equal to or larger than 10° (first threshold value) and smaller than 30° , and an inclination angle for the second determination condition is equal to or larger than 30° (second threshold value), for example.

(58) In the determination process, a posture (inclined state) of the work machine **1** is calculated based on a reference posture. The reference posture indicates a posture (inclination angle) of the main body **2** serving as a reference of the detection of a posture of the work machine **1**, and includes a posture (inclination angle) obtained when the main body **2** is located on a level surface or a posture (inclination angle) of the main body **2** obtained when the posture detection is started. The reference posture includes a posture of the main body **2** obtained when the main body **2** is placed on a level surface. Therefore, the controller **11** can perform a restriction process based on a change in a posture of the main body **2** placed on a level surface. Accordingly, the restriction process can be executed when a posture is changed from the reference posture. The reference posture may further include a posture of the main body **2** detected by the first detection unit **12** before the posture of the main body **2** changes (posture of the main body **2** at the start of the detection process). Accordingly, the controller **11** can detect a change in a posture during traveling and determine that an unstable state is entered due to a traveling motion even though the machine is in a stable state at the start of traveling.

Other Examples of Determination

(59) Example of Determination Using Posture Detection Result of Work Unit **3**

(60) In the above example, a posture of the main body **2** is detected to determine a state of the work

machine **1**, but the detection is not limited to this. For example, a posture of the work unit **3** may be detected, and the controller **11** may execute the determination process based on a result of the posture detection of the work unit **3**. In this determination example, the controller **11** specifies a posture of the work unit **3**. Specifically, the controller **11** specifies a posture of the work unit **3** based on a detection result of the second detection unit **13**, a detection result of the third detection unit **14**, and a detection result of the fourth detection unit **15**. More specifically, the controller **11** specifies positions of the boom **301**, the arm **302**, and the bucket **303** based on an angle of rotation of the boom **301**, an angle of rotation of the arm **302**, an angle of rotation of the bucket **303**, a length of the boom **301**, a length of the arm **302**, and a length of the bucket **303**. Then the controller **11** specifies a posture of the work unit **3** based on information on the position of the bucket **303**. For example, the controller **11** determines that a risk of tipping-over of the work machine **1** is high when the boom **301** and the arm **302** are extended far from the main body **2**. Furthermore, the controller **11** determines that a risk of tipping-over of the work machine **1** is low when the boom **301** and the arm **302** are retracted close to the main body **2**.

Example of Determination Using Suspended Load Detection Result

(61) As another determination method, a determination may be made based on a suspended load. In this determination example, the controller **11** determines a state of the work machine **1** based on a detection result of the sixth detection unit (load sensor) **17**. For example, the controller **11** determines that the work machine **1** is at high risk of tipping-over when the suspended load is greater than a predetermined threshold value. For example, the controller **11** determines that the work machine **1** is at low risk of tipping-over when the suspended load is equal to or smaller than the predetermined threshold value.

(62) The above is a description of the method of determination process in the present disclosure with some examples, but the method is not limited to this and various modifications may be made. For example, a plurality of determination methods may be combined to perform a determination process. Specifically, a determination process combining the posture detection result of the main body **2** and the posture detection result of the work unit **3**, a determination process combining the posture detection result of the main body **2** and the detection result of the suspended load, and a determination process combining the posture detection result of the main body **2**, the posture detection result of the work unit **3**, and the detection result of the suspended load may be employed.

(63) Restriction Process

(64) Next, a restriction process of restricting operation of the work machine **1** performed by the controller **11** will be described. Specifically, the controller **11** restricts motions of the main body **2** and/or the work unit **3** by the restriction process. Examples of the restriction on a motion of the main body **2** include restriction on a traveling motion of the traveling body **5** and a swivel motion of the swivel body **4**. In addition, the motion restriction of the work unit **3** includes restriction of rotation motions of the boom **301**, the arm **302**, and the bucket **303**.

(65) Examples of the motion restriction include restriction of a motion speed and prohibition of a motion. The prohibition of a motion includes prohibition of a motion out of a predetermined range and prohibition of a motion in a predetermined direction. In the restriction process, the controller **11**, for example, sends a control signal to the engine controller **62** of the engine unit **6** to control an engine speed, or sends a control signal to the solenoid valve **9** to control the communication state of the pilot oil. Specifically, when the controller **11** sends a control signal to the engine controller **62**, the engine speed is reduced, a discharge amount of the main pump **71** is reduced, and a flow rate of the pressure oil supplied to the hydraulic actuator is reduced, and therefore, an operation speed of the hydraulic actuator is reduced. When the controller **11** sends a control signal to the solenoid valve **9**, the flow rate of the pilot oil passing through the solenoid valve **9** changes. When the flow rate of the pilot oil passing through the solenoid valve **9** is reduced, an operation speed of the hydraulic actuator is reduced. When the pilot oil does not pass through the solenoid valve **9**, the hydraulic actuator stops. The controller **11** may restrict the rotation speed of the engine **61** in

stages.

(66) Furthermore, the controller **11** can also restrict a motion of the work machine **1** in stages in the restriction process. For example, a first restriction process that imposes relatively light restriction and a second restriction process that imposes relatively heavy restriction may be set. For example, a motion speed is restricted in the first restriction process, and a motion is prohibited in the second restriction process. Furthermore, the controller **11** can execute the restriction process based on determination conditions. For example, the first restriction process may be executed based on the first determination condition and the second restriction process may be executed based on the second determination condition. The following is a detailed description of the restriction process with specific examples.

(67) Restriction of Traveling Motion: Process of Restricting Traveling Motion of Traveling Body **5**

(68) First, a process of restricting a motion of the traveling body **5** performed by the controller **11** will be described in detail with reference to FIG. **4**. FIG. **4** is a diagram illustrating a traveling state of the work machine **1**, and specifically, a state of traveling on a level surface PL (fifth posture ST5) is illustrated in a center of the drawing, a state in which the work machine **1** enters an upward inclination (first inclined surface SL1) from the level surface PL is illustrated in a left portion in the drawing (sixth posture ST6), and a state in which the work machine **1** enters a downward inclination (second inclined surface SL2) from the level surface PL is illustrated in a right portion in the drawing (seventh posture ST7). Note that, in FIG. **4**, the work unit **3** in the work machine **1** is positioned in a direction in which the work machine **1** climbs the inclination (first inclination direction D1) and is suspending an object W. Note that the first inclination direction D1 indicates a direction from a base end of the inclined surface SL to a top of the inclined surface SL.

Specifically, the first inclination direction D1 indicates a direction in which the work machine **1** moves upward on the inclined surface SL where the main body **2** is located. The first inclination direction D1 indicates a so-called direction toward a mountain side. Although the work unit **3** is positioned in a direction in which the work unit **3** moves upward on the inclination (first inclination direction D1) in the example of FIG. **4**, the same is true of a case where the work unit **3** is positioned in a direction in which the work unit **3** moves downward on the inclination (second inclination direction D2), and therefore, a description thereof is omitted.

(69) Traveling Motion in Upward State on Inclination

(70) First, restriction control of a traveling motion in which the work machine **1** enters an upward inclination (first inclined surface SL1) from the level surface PL will be described below.

(71) Restriction of Traveling Speed

(72) When the sixth posture ST6 of the work machine **1** satisfies the determination condition described above, the controller **11** restricts a motion of the traveling body **5**, for example.

Specifically, the controller **11** reduces a traveling speed to a speed limit as shown in FIG. **3**. The speed limit is a speed low enough to avoid tipping-over of the work machine **1**. For example, the speed limit is a preset speed (first speed) or a speed obtained by multiplying a traveling speed of the work machine **1** at a time of the posture detection by a predetermined coefficient (second speed), and one of the speeds may be selected. Specifically, in a case where the preset speed is 3 km/hour and the predetermined coefficient is 0.7, when a traveling speed of the work machine **1** at a time of the posture detection is 5 km/hour, the first speed is 3 km/hour and the second speed is 3.5 km/hour. Furthermore, when a slower one of the first and second speeds is selected, the first speed (3 km/hour) is the speed limit. The speed is gradually reduced with a predetermined deceleration rate to control increase in risk of tipping-over due to a sudden change in speed. Specifically, even when the operator performs an abrupt operation, at least one of the followings is restricted (gradually decelerated): a speed of a work motion of the work unit **3**, a speed of a traveling motion of the traveling body **5**, and a speed of a swivel motion of the swivel body **4**.

(73) Prohibition of Traveling Motion

(74) Furthermore, when the sixth posture ST6 of the work machine **1** satisfies the determination

condition described above, the controller **11** may prohibit a traveling motion as the motion restriction of the traveling body **5**. For example, a traveling motion in a predetermined direction may be restricted. In the example of FIG. **4**, a traveling motion in the first inclination direction **D1** toward the first inclined surface **SL1** from the level surface **PL** (direction in which an inclination angle of the work machine **1** increases) may be prohibited. Therefore, the traveling motion of the traveling body **5** in a direction that increases the risk of tipping-over of the work machine **1** (i.e., that increases a change in a position of the center of gravity) is restricted. As a result, the work machine **1** that has entered the first inclined surface **SL1** by the traveling motion of the traveling body **5** is prevented from further traveling in the first inclination direction **D1**. In other words, a motion of the traveling body **5** in a direction in which the risk of tipping-over of the work machine **1** is lowered (e.g., a direction in which the work machine **1** returns to the reference posture) is permitted. Thus, by restricting a motion of the work machine **1** in a state of high risk of tipping-over, occurrence of tipping-over is avoided. Note that, in a traveling motion on the upward inclination, the first inclination direction **D1** in FIG. **4** corresponds to an example of a “first predetermined direction” of the present disclosure.

(75) On the other hand, the controller **11** can also restrict a traveling range as another restriction process that prohibits a traveling motion. In the process of restricting a traveling range, the controller **11** may restrict a traveling range in the first inclination direction **D1** or the second inclination direction **D2**, for example.

(76) In this way, the controller **11** executes the restriction process, such as restriction of a traveling speed or prohibition of a traveling motion, based on a determination result indicating a posture of the work machine **1**. In this case, the controller **11** may execute the restriction process in stages, and for example, a traveling speed may be restricted as a first restriction process based on the first determination condition and a traveling direction may be restricted as a second restriction process based on the second determination condition.

(77) Traveling Motion in Downward State on Inclination

(78) Next, a traveling motion in which the work machine **1** enters a downward inclination (second inclined surface **SL2**) from the level surface **PL** that is also a target of the restriction process similarly to the traveling motion on the upward inclination described above will be described hereinafter.

(79) Restriction of Traveling Speed

(80) Furthermore, when the seventh posture **ST7** of the work machine **1** satisfies the determination condition described above, the controller **11** reduces a traveling speed to the speed limit as the motion restriction of the traveling body **5**.

(81) Prohibition of Traveling Motion

(82) Furthermore, when the seventh posture **ST7** of the work machine **1** satisfies the determination condition described above, the controller **11** may restrict a traveling motion in a direction in which the risk of tipping-over increases as the prohibition of the traveling motion. Note that, in the traveling motion on the downward inclination, the direction in which the risk of tipping-over increases (second inclination direction **D2**) corresponds to an example of a “second predetermined direction” of the present disclosure.

(83) Restriction of Swivel Motion

(84) Next, a process of restricting a motion of the swivel body **4** performed by the controller **11** will be described with reference to FIGS. **5A** to **8**. FIG. **5A** is a diagram illustrating the work machine **1** located on the inclined surface **SL**. As illustrated in FIG. **5A**, the work unit **3** of the work machine **1** is located in the first inclination direction **D1** and suspends an object **W**.

(85) Swivel Motion in Upward State on Inclination

(86) First, restriction control on a swivel motion of the work machine **1** in an upward state on the inclined surface **SL** will be described.

(87) In FIG. **5B**, an 11th posture **ST11** indicates a posture of the work machine **1** obtained when an

angle of the swivel body **4** relative to the traveling body **5** is a reference angle. The reference angle is, for example, an angle of “0°” of the swivel body **4** relative to the traveling body **5**. In FIG. 5B, the work unit **3** of the work machine **1** in the 11th posture ST**11** is positioned in the first inclination direction D**1**.

(88) A 12th posture ST**12** indicates a posture of the work machine **1** obtained when the swivel body **4** swivels leftward relative to the traveling body **5** at a predetermined angle from the reference angle. The predetermined angle is, for example, an angle of “90°” of the swivel body **4** relative to the traveling body **5**. In FIG. 5B, the work unit **3** of the work machine **1** in the 12th posture ST**12** is in a state in which the work unit **3** intersects with the first inclination direction D**1** and is positioned on a side of the first crawler **501A**.

(89) A 13th posture ST**13** indicates a posture of the work machine **1** obtained when the swivel body **4** swivels rightward relative to the traveling body **5** at a predetermined angle from the reference angle. The predetermined angle is, for example, an angle of “90°” of the swivel body **4** relative to the traveling body **5**. In FIG. 5B, the work unit **3** of the work machine **1** in the 13th posture ST**13** is in a state in which the work unit **3** intersects with the first inclination direction D**1** and is positioned on a side of the second crawler **501B**.

(90) The swivel body **4** of the work machine **1** swivels in a first swivel direction RD**1**. The first swivel direction RD**1** indicates a swivel direction from the 13th posture ST**13** to the 11th posture ST**11**. In FIG. 5B, the first swivel direction RD**1** indicates a direction in which the swivel body **4** swivels such that the work unit **3** faces up the inclined surface SL where the main body **2** is located.

(91) The swivel body **4** of the work machine **1** swivels in a second swivel direction RD**2**. The second swivel direction RD**2** indicates a swivel direction from the 11th posture ST**11** to the 13th posture ST**13**. In FIG. 5B, the second swivel direction RD**2** indicates a direction in which the swivel body **4** swivels such that the work unit **3** faces down the inclined surface SL where the main body **2** is located.

(92) The swivel body **4** of the work machine **1** swivels in a third swivel direction RD**3**. The third swivel direction RD**3** indicates a swivel direction from the 12th posture ST**12** to the 11th posture ST**11**. In FIG. 5B, the third swivel direction RD**3** indicates a direction in which the swivel body **4** swivels such that the work unit **3** faces up the inclined surface SL where the main body **2** is located.

(93) The swivel body **4** of the work machine **1** swivels in a fourth swivel direction RD**4**. The fourth swivel direction RD**4** indicates a swivel direction from the 11th posture ST**11** to the 12th posture ST**12**. In FIG. 5B, the fourth swivel direction RD**4** indicates a direction in which the swivel body **4** swivels such that the work unit **3** faces down the inclined surface SL where the main body **2** is located.

(94) Restriction of Swivel Speed

(95) As shown in FIGS. 5A and 5B, when a posture of the work machine **1** positioned on the inclined surface SL satisfies the first determination condition, the controller **11** restricts a swivel motion of the swivel body **4**. Specifically, the controller **11** reduces the swivel speed to a speed limit irrespective of the swivel directions RD**1** to RD**4** by means of a method the same as the speed restriction process described above.

(96) Prohibition of Swivel Motion

(97) Furthermore, when the 11th posture ST**11** of the work machine **1** satisfies the determination condition described above, the controller **11** may prohibit a swivel motion in a predetermined direction as a motion restriction of the swivel body **4**. In the example shown in FIGS. 5A and 5B, a swivel motion from an upper direction of the inclined surface SL to a lower direction that increases the risk of tipping-over of the work machine **1** (the second swivel direction RD**2** and the fourth swivel direction RD**4**) may be prohibited. In other words, the second swivel direction RD**2** and the fourth swivel direction RD**4** shown in FIG. 5B individually correspond to examples of a “first predetermined direction” of the present disclosure.

(98) On the other hand, the controller **11** may also restrict a swivel range as another restriction

process that prohibits a swivel motion. In a process of restricting a swivel range, the controller **11** may restrict a swivel range to a range TR in which the risk of tipping-over does not increase (a range in which a change in a position of a center of gravity does not increase), for example. In this way, a restriction process suitable for a work environment may be executed by enabling selection of prohibition of a motion in a predetermined direction or prohibition of a motion outside a predetermined range. For example, in the example shown in FIGS. 5A and 5B, the restriction process of prohibiting a motion in the predetermined direction prohibits a swivel motion, and therefore, risk avoidance is substantially difficult. However, when the restriction process of prohibiting a motion out of the predetermined range is executed, a swivel motion in the predetermined range is enabled, and therefore, the risk avoidance is enabled.

(99) Note that, as shown in FIGS. 6A and 6B, when the work unit **3** of the work machine **1** is positioned in the second inclination direction D2 (a downward state on an inclination), only a swivel motion from a lower direction to an upper direction on the inclined surface SL in which the risk of tipping-over is low is permitted for the work unit **3**, and therefore, the restriction process described above is not performed.

(100) In this way, the controller **11** executes the restriction process, such as restriction of a swivel speed or prohibition of a swivel motion, based on a determination result indicating a posture of the work machine **1**. In this case, as with the traveling motion described above, the controller **11** may execute the restriction process in stages, and for example, a swivel speed may be restricted as a first restriction process based on the first determination condition and a swivel direction may be restricted as a second restriction process based on the second determination condition.

(101) Swivel Motion in Lateral State on Inclination

(102) Next, restriction control on a swivel motion of the work machine **1** in a lateral state on the inclined surface SL will be described.

(103) FIG. 7A is another diagram illustrating the work machine **1** located on the inclined surface SL. As illustrated in FIG. 7A, the work unit **3** of the work machine **1** is positioned in a direction intersecting with the first inclination direction D1 or the second inclination direction D2 and suspends the object W.

(104) In FIG. 7B, the work unit **3** of the work machine **1** in the 11th posture ST11 intersects with the first inclination direction D1 or the second inclination direction D2. In FIG. 7B, the work unit **3** of the work machine **1** in the 12th posture ST12 is positioned in the second inclination direction D2. In FIG. 7B, the work unit **3** of the work machine **1** in the 13th posture ST13 is positioned in the first inclination direction D1.

(105) The swivel body **4** of the work machine **1** swivels in the first swivel direction RD1, the second swivel direction RD2, the third swivel direction RD3, and the fourth swivel direction RD4. In FIG. 7B, the first swivel direction RD1 and the fourth swivel direction RD4 indicate a direction in which the swivel body **4** swivels such that the work unit **3** faces down the inclined surface SL where the main body **2** is located. In FIG. 7B, the second swivel direction RD2 and the third swivel direction RD3 indicate a direction in which the swivel body **4** swivels such that the work unit **3** faces up the inclined surface SL where the main body **2** is located.

(106) For example, as shown in FIG. 7B, when the swivel body **4** of the work machine **1** in the 11th posture ST11 swivels in the first swivel direction RD1 or the fourth swivel direction RD4, the swivel body **4** swivels in the direction down the inclined surface SL where the main body **2** is located. In other words, the first swivel direction RD1 and the fourth swivel direction RD4 shown in FIG. 7B correspond to examples of the “first predetermined direction” of the present disclosure.

(107) Restriction of Swivel Speed

(108) When the 11th posture ST11 of the work machine **1** satisfies the determination condition described above, the controller **11** reduces a swivel speed to the speed limit as the motion restriction of the swivel body **4**, for example, by means of a method the same as the speed restriction process described above.

(109) Prohibition of Swivel Motion

(110) Furthermore, when the 11th posture **ST11** of the work machine **1** satisfies the determination condition described above, the controller **11** may restrict a swivel motion in a direction in which the risk of tipping-over increases as the prohibition of a swivel motion by means of a method the same as the prohibition restriction process described above. Note that, in the swivel motion in the lateral state on the inclination, the direction (fourth swivel direction **RD4**) in which the risk of tipping-over increases corresponds to an example of the “first predetermined direction” of the present disclosure.

(111) On the other hand, the controller **11** may also restrict a swivel range as another restriction process that prohibits a swivel motion. In the process of restricting a swivel range, the controller **11** may restrict a swivel range to a range in which the risk of tipping-over does not increase (a range in which a change in a position of a center of gravity does not increase), for example.

(112) In this way, the controller **11** executes the restriction process, such as restriction of a swivel speed or prohibition of a swivel motion, based on a determination result indicating a posture of the work machine **1**. In this case, as with the traveling motion described above, the controller **11** may execute the restriction process in stages, and for example, a swivel speed may be restricted as a first restriction process based on the first determination condition and a swivel direction may be restricted as a second restriction process based on the second determination condition.

(113) Pattern Table Showing Method for Restricting Swivel Motion

(114) The above description shows the specific examples of the processes of restricting a swivel motion, but the restriction processes may also be performed based on a predetermined pattern table. Therefore, the pattern table of the swivel body **4** of the work machine **1** will now be described with reference to FIG. **8**. FIG. **8** is a diagram illustrating a pattern table of the swivel body **4** of the work machine **1** according to this embodiment. A pattern table TB for the swivel body **4** shown in FIG. **8** is stored in the storage unit **21**. The pattern table TB shows a state of the work machine **1** and a possible motion of the swivel body **4** corresponding to the state of the work machine **1**. Specifically, the pattern table TB includes state information **T11**, state information **T12**, state information **T13**, state information **T14**, first swivel information **T15** and second swivel information **T16**.

(115) The state information **T11** indicates a state of the traveling body **5**. The state information **T12** indicates a state of the blade **511**. The state information **T13** indicates a state of the swivel body **4**. The state information **T14** indicates a state of the work unit **3**.

(116) The first swivel information **T15** indicates whether the swivel body **4** may swivel to the right. The possibility of swiveling of the swivel body **4** to the right is indicated by a symbol. When the swiveling to the right of the swivel body **4** is permitted, “O” is shown. When swiveling to the right of the swivel body **4** is not permitted, “x” is shown.

(117) The second swivel information **T16** indicates whether the swivel body **4** may swivel to the left. The possibility of swiveling of the swivel body **4** to the left is indicated by a symbol. When the swiveling to the left of the swivel body **4** is permitted, “O” is shown. When swiveling to the left of the swivel body **4** is not permitted, “x” is shown.

(118) For example, the state information **T11** in the pattern table TB indicates that a front-rear direction of the inclined surface **SL** and the traveling body **5** are parallel to each other. The state information **T12** in the pattern table TB indicates that the blade **511** is located in the first inclination direction **D1**. The state information **T13** in the pattern table TB indicates that an angle of the swivel body **4** relative to the traveling body **5** is “0°”. The state information **T14** in the pattern table TB indicates that the work unit **3** is located in the first inclination direction **D1**. In this case, the first swivel information **T15** indicates that the swiveling to the right of the swivel body **4** is not permitted. In other words, the first swivel information **T15** indicates that a motion of the work unit **3** in a retracting direction **DB** is restricted. Furthermore, the second swivel information **T16** indicates that the swiveling to the left of the swivel body **4** is permitted.

(119) In this way, since content of the restriction process is predetermined using the pattern table, system development for executing the restriction process is facilitated.

(120) **Restriction of Motion of Work Unit 3: Motion of Work Unit 3 in Upward State on Inclination**

(121) First, restriction control of restricting a motion of the work unit 3 in a state in which the work machine is located on the upward inclined surface SL will be described.

(122) A process of restricting a motion of the work unit 3 performed by the controller 11 will be described with reference to FIGS. 9 to 11. As illustrated in FIG. 9A, the work unit 3 of the work machine 1 is located in an upward direction on the inclination (first inclination direction D1) and suspends an object W.

(123) FIG. 9A also shows the work machine 1 in the first posture ST1 and the work machine 1 in the second posture ST2. The first posture ST1 is in a state in which a position of the work unit 3 is in the first inclination direction D1 relative to a position of the work unit 3 in the second posture ST2. The second posture ST2 is in a state in which a position of the work unit 3 is in the second inclination direction D2 relative to a position of the work unit 3 in the first posture ST1. The second inclination direction D2 indicates a direction opposite to the first inclination direction D1. Specifically, the second inclination direction D2 indicates a direction from the top of the inclined surface SL to the base end of the inclined surface SL. Specifically, the second inclination direction D2 indicates a direction downward the inclined surface SL where the main body 2 is located. The second inclination direction D2 indicates a so-called direction toward a valley side. The second inclination direction D2 corresponds to an example of the “first predetermined direction”.

(124) FIG. 9B is a plan view of the work machine 1 of FIG. 9A in the first posture ST1. FIG. 9C is a plan view of the work machine 1 of FIG. 9A in the second posture ST2.

(125) **Restriction of Motion Speed of Work Unit 3**

(126) As illustrated in FIGS. 9A to 9C, when the first posture ST1 of the work machine 1 satisfies the determination condition described above, the controller 11 restricts a motion speed of the work unit 3. Specifically, the controller 11 reduces the motion speed of the work unit 3 by the restriction process.

(127) **Prohibition of Motion of Work Unit 3**

(128) Furthermore, when the first posture ST1 of the work machine 1 satisfies the determination condition described above, the controller 11 may prohibit a motion of the work unit 3 as the motion restriction of the work unit 3. For example, a motion of the work unit 3 in a predetermined direction may be restricted. In the example in FIGS. 9A to 9C, a motion from an upper side to a lower side of the inclined surface SL may be prohibited. In other words, the work unit 3 is prevented from moving in the second inclination direction D2 (retracting direction DB) and entering the second posture ST2 from the first posture ST1. Therefore, a work motion of the work unit 3 in the direction in which the risk of tipping-over of the work machine 1 increases (a change in a position of the center of gravity increases) is restricted. As a result, the work machine 1 located on the inclined surface SL may be prevented from tipping over due to a work motion of the work unit 3.

(129) On the other hand, the controller 11 may also restrict a motion range of the work unit 3 as another restriction process that prohibits a motion of the work unit 3. The controller 11 may restrict a motion range of the work unit 3 to a range in which the risk of tipping-over does not increase (a range in which a change in a position of the center of gravity does not increase), for example.

(130) **Motion of Work Unit 3 in Downward State on Inclination**

(131) Next, restriction control of restricting a motion of the work unit 3 in a state in which the work machine 1 is located on the downward inclined surface SL will be described.

(132) FIG. 10A is a diagram illustrating the work machine 1 located on the inclined surface SL. As illustrated in FIG. 10A, the work unit 3 of the work machine 1 is located in a downward direction of the inclination (second inclination direction D2) and suspends an object W.

(133) FIG. 10A also shows the work machine 1 in the third posture ST3 and the work machine 1 in

the fourth posture ST4. The third posture ST3 indicates a state in which a position of the work unit 3 is in the second inclination direction D2 relative to a position of the work unit 3 in the fourth posture ST4. The fourth posture ST4 indicates in a state in which a position of the work unit 3 is in the first inclination direction D1 relative to a position of the work unit 3 in the third posture ST3.

(134) Restriction of Motion Speed of Work Unit 3

(135) As illustrated in FIG. 10B, when the third posture ST3 of the work machine 1 satisfies the determination condition described above, the controller 11 restricts a motion of the work unit 3. Specifically, the controller 11 reduces the motion speed of the work unit 3 by the restriction process. An extending direction DA in FIG. 10B is the same direction as the second inclination direction D2. The second inclination direction D2 in FIG. 10B corresponds to an example of the “first predetermined direction”.

(136) Prohibition of Motion of Work Unit 3

(137) Furthermore, when the third posture ST3 of the work machine 1 satisfies the determination condition described above, the controller 11 may prohibit a motion of the work unit 3 as the motion restriction of the work unit 3. For example, a motion of the work unit 3 in a predetermined direction may be restricted. In the example in FIGS. 10A to 10C, a motion from an upper side to a lower side of the inclined surface SL may be prohibited. In other words, the work unit 3 is prevented from moving in the second inclination direction D2 (extending direction DA) and entering the third posture ST3 from the fourth posture ST4.

(138) On the other hand, the controller 11 may also restrict a motion range of the work unit 3 as another restriction process that prohibits a motion of the work unit 3. The controller 11 may restrict a motion range of the work unit 3 to a range in which the risk of tipping-over does not increase (a range in which a change in a position of the center of gravity does not increase), for example.

(139) Pattern Table Showing Method for Restricting Motion of Work Unit 3

(140) The above description shows the specific examples of the processes of restricting a motion of the work unit 3, but the restriction processes may also be performed based on a predetermined pattern table. Therefore, the process of the controller 11 in restriction of a motion of the work unit 3 will now be described in more detail with reference to FIGS. 2 to 11. FIG. 11 shows a pattern table TA for the work unit 3.

(141) The pattern table TA for the work unit 3 shown in FIG. 11 is stored in the storage unit 21. The pattern table TA shows a state of the work machine 1 and a possible work of the work unit 3 corresponding to the state of the work machine 1. Specifically, the pattern table TA includes state information T1, state information T2, state information T3, state information T4, first work information T5, and second work information T6.

(142) The state information T1 indicates a state of the traveling body 5. Specifically, a position of the traveling body 5 relative to the inclined surface SL is indicated. Examples of the state of the traveling body 5 include a state in which the inclined surface SL and the front-rear direction of the traveling body 5 are parallel to each other and a state in which the inclined surface SL and the front-rear direction of the traveling body 5 intersect with each other.

(143) The state information T2 indicates a state of the blade 511.

(144) Specifically, a position of the blade 511 relative to the inclined surface SL is indicated. Examples of the state of the blade 511 include a state in which the blade 511 is positioned in the first inclination direction D1 and a state in which the blade 511 is positioned in the second inclination direction D2.

(145) The state information T3 indicates a state of the swivel body 4. Specifically, the state information T3 indicates an angle of the swivel body 4 relative to the traveling body 5. Examples of the state of the swivel body 4 include a state in which the angle of the swivel body 4 relative to the traveling body 5 is in a range from “0°” to “90°”.

(146) The state information T4 indicates a state of the work unit 3. Specifically, the state information T4 indicates a position of the work unit 3 relative to the inclined surface SL. Examples

of the state of the work unit **3** include a state in which the work unit **3** is positioned in the first inclination direction **D1** and a state in which the work unit **3** is positioned in the second inclination direction **D2**.

(147) The first work information **T5** indicates whether the work unit **3** may move in the extending direction **DA**. The possibility of a motion of the work unit **3** in the extending direction **DA** is indicated by a symbol. When a motion in the extending direction **DA** of the work unit **3** is permitted, “O” is shown. When a motion in the extending direction **DA** of the work unit **3** is not permitted, “x” is shown.

(148) The second work information **T6** indicates whether the work unit **3** can move in the retracting direction **DB**. The possibility of a motion of the work unit **3** in the retracting direction **DB** is indicated by a symbol. When a motion in the retracting direction **DB** of the work unit **3** is permitted, “O” is shown. When a motion in the retracting direction **DB** of the work unit **3** is not permitted, “x” is shown.

(149) For example, the state information **T1** in the pattern table **TA** indicates that front-rear directions of the inclined surface **SL** and the traveling body **5** are parallel to each other. The state information **T2** in the pattern table **TA** indicates that the blade **511** is located in the first inclination direction **D1**. The state information **T3** in the pattern table **TA** indicates that an angle of the swivel body **4** relative to the traveling body **5** is “0°”. The state information **T4** in the pattern table **TA** indicates that the work unit **3** is located in the first inclination direction **D1**. In this case, the first work information **T5** permits a motion of the work unit **3** in the extending direction **DA**.

Furthermore, the second work information **T6** does not permit a motion of the work unit **3** in the retracting direction **DB**. In other words, the second work information **T6** restricts a motion of the work unit **3** in the retracting direction **DB**.

(150) In this way, since content of the restriction process is predetermined using the pattern table, system development for executing the restriction process is facilitated.

(151) Switching of Work Mode

(152) In the work machine **1** of this embodiment, a plurality of work modes may be provided, and the controller **11** may execute the restriction process in a predetermined work mode selected from among the work modes. Examples of the work mode include an excavation mode in which the bucket **303** is used for excavation and a crane mode in which operation is performed while a load is suspended on the crane hook of the bucket **303**. The controller **11** may then execute the restriction process based on the determination condition described above when the crane mode is selected, for example. In the crane mode, the risk of tipping-over of the work machine **1** is higher than in the other work modes because a considerable load is suspended by ropes or the like, and in addition, load swing may occur during the operation. On the other hand, in the excavation mode, the bucket **303** may temporarily accommodate an excavated object, but the risk of tipping over is lower than in the crane mode. Therefore, the controller **11** executes the restriction process during the work mode with a higher risk of tipping-over, thereby preventing a reduction in workability during the work mode with a lower risk of tipping-over. The crane mode corresponds to an example of the “predetermined work mode”.

(153) Furthermore, in the above example, the controller **11** executes the restriction process when the determination condition is satisfied during the predetermined work mode, but the operation is not limited to this. For example, the controller **11** may allow switching of the work mode when the determination condition is satisfied. In this case, switching to the crane mode is permitted in accordance with a posture of the main body **2**. As a result, a crane operation in a posture with a high risk of tipping-over can be prevented, and occurrence of tipping-over of the work machine **1** can be avoided.

(154) Reporting Process of Reporting Unit **19**

(155) Next, referring to FIG. **12**, the reporting unit **19** will be described in detail. FIG. **12** is a diagram illustrating an image displayed on a display unit **190** of the reporting unit **19**. The image

displayed on the display unit **190** of the reporting unit **19** includes a first image **191** and a second image **192**. The first image **191** indicates an angle corresponding to a posture of the main body **2** of the work machine **1**. The second image **192** indicates the restriction process being performed by the controller **11**.

(156) As shown in FIG. **12**, the reporting unit **19** reports a detection result of the first detection unit **12**. Accordingly, the operator can be informed that the work machine **1** is located on an inclined surface. As a result, the operator can be encouraged to move the work machine **1** to a different position from the inclined surface.

(157) Furthermore, as shown in FIG. **12**, the reporting unit **19** reports content of the restriction process. Accordingly, the operator can be informed of content of the restriction process being performed by the controller **11**. As a result, the operator can recognize the content of the restriction process.

(158) When a change in a posture of the main body **2** satisfies the first determination condition, the reporting unit **19** can report content of the first restriction process. Furthermore, when a change in a posture of the main body **2** satisfies the second determination condition, the reporting unit **19** can report content of the second restriction process.

(159) Furthermore, when a change in a posture of the main body **2** satisfies the determination condition in the second determiner, the reporting unit **19** provides a warning. Accordingly, it is possible to recognize that the work machine **1** may tip over. As a result, the operator can be encouraged to move the work machine **1** to a position where operation is available.

(160) Flow of Restriction Process of Controller **11**

(161) Referring now to FIG. **13**, a process executed by the controller **11** of the work machine **1** will be described. FIG. **13** is a flowchart of a process executed by the controller **11** of the work machine **1**. The process performed by the controller **11** of the work machine **1** includes step **S101** to step **S112**.

(162) In step **S101**, the operating unit **20** accepts an operation of switching to the crane mode of the work machine **1** performed by the operator. The process then proceeds to step **S102**.

(163) In step **S102**, the controller **11** determines whether a posture of the main body **2** satisfies the first determination condition. When a posture of the main body **2** does not satisfy the first determination condition (No in step **S102**), the process proceeds to step **S103**. When a posture of the main body **2** satisfies the first determination condition (Yes in step **S102**), the process proceeds to step **S104**.

(164) When the determination is negative in step **S102**, the controller **11** causes the reporting unit **19** to report information on the posture of the main body **2** and other information in step **S103**. The process then returns to step **S102**.

(165) When the determination is affirmative in step **S102**, the controller **11** permits mode switching to the crane mode and executes a mode switching process in step **S104**. In subsequent processes, the work machine **1** operates in the crane mode. The process then proceeds to step **S105**.

(166) In step **S105**, the controller **11** determines whether a posture of the main body **2** satisfies the first determination condition. When the posture of the main body **2** does not satisfy the first determination condition (No in step **S105**), the process proceeds to step **S109**. When the posture of the main body **2** satisfies the first determination condition (Yes in step **S105**), the process proceeds to step **S107**.

(167) When the determination is affirmative in step **S105**, the controller **11** executes the first restriction process in step **S107**. Specifically, the controller **11** reduces a motion speed of the main body **2** and/or the work unit **3**. The process then proceeds to step **S108**.

(168) In step **S108**, the controller **11** causes the reporting unit **19** to report content of the first restriction process. The process then proceeds to step **S109**.

(169) When the determination is negative in step **S105** or after step **S108**, the controller **11** determines whether a posture of the main body **2** satisfies the second determination condition in

step **S109**. When a posture of the main body **2** does not satisfy the second determination condition (No in step **S109**), the process proceeds to step **S106**. When a posture of the main body **2** satisfies the second determination condition (Yes in step **S109**), the process proceeds to step **S110**.

(170) When the determination is affirmative in step **S109**, the controller **11** executes the second restriction process in step **S110**. Specifically, the controller **11** prohibits a motion of the main body **2** and/or the work unit **3**. The process then proceeds to step **S111**.

(171) In step **S111**, the controller **11** causes the reporting unit **19** to report content of the second restriction process. The process then proceeds to step **S112**.

(172) In step **S112**, the controller **11** determines whether a condition for terminating the crane mode is satisfied. When the determination is negative (No in step **S112**), the process returns to step **S104**. When the determination is affirmative (Yes in step **S112**), the process is terminated.

(173) When the determination is negative in step **S109**, the controller **11** cancels the restriction state in step **S106**. The process then returns to step **S104**.

(174) The embodiment of the present disclosure has been described hereinabove with reference to the drawings. However, the present disclosure is not limited to the embodiment described above, and can be embodied in various modes in a range without departing from its spirit. Various inventions can be formed by combining the plurality of components disclosed in the above embodiment as appropriate. For example, some of the components may be removed from all the components shown in the embodiment. In addition, the components in the different examples may be combined as appropriate. The drawings are schematically illustrated with each component as a main subject in order to facilitate understanding, and the thicknesses, the lengths, the numbers, the spacings, and so on of the illustrated components may be different from actual ones due to convenience of the drawings. Furthermore, the speeds, the materials, the shapes, the sizes, and so on of the individual components illustrated in the above embodiment are merely examples and are not particularly limited, and various modifications may be made without substantially departing from the configurations of the present disclosure.

(175) (1) Although the controller **11** of the work machine **1** of the first embodiment restricts at least one of a motion of the work unit **3** and a motion of the main body **2** in the crane mode, the restriction is not limited to this. For example, when the work unit **3** is in the mode of executing earth excavation work, the controller **11** may restrict at least one of a motion of the work unit **3** and a motion of the main body **2**. Specifically, the controller **11** restricts at least one of a motion of the work unit **3** and a motion of the main body **2** based on a detection result of the first detection unit **12** and a detection result of the sixth detection unit **17**. The controller **11** can calculate a weight of soil accommodated in the bucket **303** based on a pressure of working oil supplied to the boom cylinder **51a** indicated by a detection result of the sixth detection unit **17**. Therefore, the controller **11** may restrict at least one of a motion of the work unit **3** and a motion of the main body **2** based on an inclination of the main body **2** and a weight of soil.

(176) (2) Although the controller **11** of this embodiment restricts a motion of the work unit **3** based on the pattern table TA, the reference of the restriction is not limited to this. For example, the controller **11** may restrict a motion of the work unit **3** based on a position of the center of gravity of the work machine **1**.

(177) For example, the controller **11** calculates a position of the center of gravity of the work machine **1** based on size information of the work machine **1**, weight information of the work machine **1**, a posture of the main body **2**, a posture of the work unit **3**, angle information of the swivel body **4**, and load information. Specifically, the controller **11** calculates a position of the center of gravity of the work machine **1** based on the size information of the work machine **1**, the weight information of the work machine **1**, and detection results of the first to sixth detection units **12** to **17**. The controller **11** then calculates the possibility of tipping-over of the work machine **1** based on the position of the center of gravity of the work machine **1**. The controller **11** then restricts a motion of the work unit **3** based on a calculation result of the controller **11**. As a result, the

controller **11** can precisely restrict a motion of the work unit **3**.

(178) (3) Although the controller **11** of this embodiment restricts a motion of the swivel body **4** based on the pattern table TB, the reference of the restriction is not limited to this. For example, the controller **11** may restrict a motion of the swivel body **4** based on a position of the center of gravity of the work machine **1**.

(179) For example, the controller **11** calculates a position of the center of gravity of the work machine **1** based on the size information of the work machine **1**, the weight information of the work machine **1**, and detection results of the first to sixth detection units **12** to **17**. The controller **11** then calculates the possibility of tipping-over of the work machine **1** based on the position of the center of gravity of the work machine **1**. The controller **11** then restricts a motion of the swivel body **4** based on a calculation result of the controller **11**. Consequently, the controller **11** can precisely restrict a motion of the swivel body **4**.

(180) (4) The storage unit **21** of the work machine **1** of this embodiment stores a detection result of the first detection unit **12**. The controller **11** can perform a control process based on the detection result stored in the storage unit **21**. For example, when an inclination of the inclined surface SL progressively increases, a direction in which the inclination of the inclined surface SL increases (i.e., a direction in which a change in posture of the main body **2** increases) and a magnitude of the inclination change can be identified by accumulating detection results of the first detection unit **12** in the storage unit **21**. Accordingly, the controller **11** can estimate a change in a posture of the main body **2** based on the detection result of the first detection unit **12** stored in the storage unit **21**. Therefore, the controller **11** can perform the restriction process in advance before the main body **2** reaches an estimated inclination angle. As a result, the restriction process can be performed before the work machine **1** is positioned on the inclined surface SL. Note that the direction in which the inclination of the inclined surface SL increases corresponds to the “second predetermined direction” in the present disclosure.

(181) The controller **11** can estimate a change in a posture of the main body **2** caused by a traveling motion of the traveling body **5** based on the detection result of the first detection unit **12** stored in the storage unit **21**. The controller **11** then executes the restriction process based on an estimated result. Therefore, the controller **11** can perform the restriction process of restricting a motion of the work machine **1** based on the change in a posture of the main body **2** estimated by the controller **11**. As a result, the restriction process may be executed before the work machine **1** is positioned on the inclined surface SL and tipping-over of the work machine **1** may be avoided.

(182) (5) The controller **11** of the work machine **1** of this embodiment may use a detection result of the seventh detection unit **18** to restrict a motion of the work machine **1**. The detection result of the seventh detection unit **18** is stored in the storage unit **21**. The seventh detection unit **18** can detect road surface conditions. Examples of the road surface conditions include an inclination angle of a road surface. The controller **11** specifies a road surface condition based on a detection result of the seventh detection unit **18** stored in the storage unit **21**. Accordingly, based on the road surface condition specified by the controller **11**, the controller **11** can restrict a motion of the work machine **1**. As a result, tipping-over of the work machine **1** located on the inclined surface SL may be avoided.

(183) In addition, since the detection result of the seventh detection unit **18** stored in the storage unit **21** is used, the controller **11** can specify an angle of the inclined surface SL in a traveling direction of the work machine **1**. Accordingly, the work machine **1** may be prevented from moving close to the inclined surface SL in the traveling direction of the work machine **1**. As a result, the work machine **1** is prevented from entering the inclined surface SL in which the work machine **1** is likely to tip over.

INDUSTRIAL APPLICABILITY

(184) The present disclosure provides a work machine and has industrial applicability.

REFERENCE SIGNS LIST

(185) **1:** Work machine **2:** Main body **3:** Work unit **4:** Swivel body **5:** Traveling body **12:** First detection unit **111:** Restrictor **112:** Specifier **113:** First determiner **114:** Second determiner

Claims

1. A work machine comprising: a work unit that executes work; a main body that supports the work unit; a detection unit that detects a posture of the main body; and a controller that prevents the work machine from tipping over by executing a restriction process of restricting at least one of a motion of the work unit and a motion of the main body, based on a result of detection of the detection unit, wherein the controller restricts a motion of the work unit in a first predetermined direction in the restriction process, and the first predetermined direction indicates a downward direction of an inclined surface where the main body is positioned, and the main body supports the work unit and includes a swivel body supported by a traveling body in a swivelable manner, and the controller restricts a swivel motion of the swivel body in the first predetermined direction in the restriction process.
2. The work machine according to claim 1, wherein the controller executes the restriction process based on a change in the posture of the main body from a reference posture.
3. The work machine according to claim 2, wherein the reference posture includes the posture of the main body obtained when the main body is disposed on a level surface.
4. The work machine according to claim 1, wherein the main body includes the traveling body that travels, and the controller executes the restriction process based on a change in the posture of the main body caused by traveling of the traveling body.
5. The work machine according to claim 1, wherein the controller specifies a posture of the work unit, and executes the restriction process based on a posture of the work unit and the posture of the main body.
6. The work machine according to claim 1, wherein the restriction process includes a first restriction process of restricting a motion speed and a second restriction process of prohibiting a motion.
7. The work machine according to claim 1, wherein the controller executes the restriction process based on a determination condition indicating an inclination angle of the main body.
8. The work machine according to claim 7, wherein the determination condition includes a first determination condition and a second determination condition different from the first determination condition, and the controller executes a first restriction process based on the first determination condition and executes a second restriction process based on the second determination condition.
9. The work machine according to claim 1, wherein the controller restricts a traveling motion of the traveling body in a second predetermined direction in the restriction process, and the second predetermined direction indicates a direction in which a change in the posture of the main body increases.
10. The work machine according to claim 1, further comprising a reporting unit that reports the detection result of the detection unit.
11. The work machine according to claim 10, wherein the reporting unit reports content of the restriction process.
12. The work machine according to claim 1, further comprising: a storage unit that stores the detection result of the detection unit, wherein the controller executes the restriction process based on the detection result stored in the storage unit.
13. The work machine according to claim 12, wherein the controller estimates a change in the posture of the main body caused by a traveling motion based on the detection result stored in the storage unit and executes the restriction process based on the estimation.
14. The work machine according to claim 1, wherein the work machine has a plurality of work modes that are switchable from one to another, and the controller executes the restriction process

based on the detection result of the detection unit in a predetermined one of the work modes.
15. The work machine according to claim 14, wherein the controller permits switching to a predetermined one of the work modes based on the detection result of the detection unit.
