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Inventor(s)	IWAKI; Koji et al.

ELECTRIC TRANSMISSION AND WORK VEHICLE INCLUDING THE SAME

Abstract

[Problem] An electric transmission is to be shared among different models and specifications, and can be easily adapted to, for example, a plurality of models and specifications of a work vehicle only by developing variations of power transmissions such as a transmission case excluding the electric transmission. [Solution] The electric transmission includes a work electric motor, a travel electric motor, and a power combining mechanism that combines the output of the electric motors. The output of the power combining mechanism is changeable by variably controlling at least the output of the travel electric motor. The electric motors and the power combining mechanism are assembled in a common casing to form a unit. The output of the work electric motor and the output of the power combining mechanism can be respectively taken out from the casing.

Inventors: **IWAKI; Koji (Amagasaki-shi, JP), ADACHI; Hitoshi (Amagasaki-shi, JP), IMA; Akihiro (Amagasaki-shi, JP), SHINOHARA; Toshinobu (Amagasaki-shi, JP), YAMAGISHI; Noriyuki (Amagasaki-shi, JP)**

Applicant: **KANZAKI KOKYUKOKI MFG. CO., LTD.** (Amagasaki-shi, JP)

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present invention claims priority under 35 U.S.C. § 119 to Japanese Application No. 2024-019130, filed on Feb. 13, 2024, the entire contents of which being incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to an electric transmission and a work vehicle including the same.

BACKGROUND ART

[0003] In recent years, motorization of power sources mounted on various work vehicles has been promoted as a countermeasure against global warming, exhaust gas regulations, and the like. For example, Patent Document 1 discloses a work vehicle including a work electric motor, a travel electric motor, and a planetary gear mechanism that combines outputs of the electric motors, in which a portion of the output of the work electric motors is transmitted to a work drive system, and a combined output of the planetary gear mechanism is transmitted to a travel drive system.

PRIOR ART DOCUMENT

Patent Document

[0004] Patent Document 1: Japanese Unexamined Patent Application Publication No. 2013-141955

SUMMARY OF INVENTION

Technical Problem

[0005] In recent work vehicles, it is strongly demanded to contribute to cost reduction and effective use of resources by weight reduction and simplification of manufacturing processes. For this purpose, it is considered desirable that not only a platform (a basic portion of machine body design) but also a power transmission such as a transmission case can be shared as much as possible between models.

[0006] However, in general, the power transmission of a work vehicle is usually different for each model or each specification in accordance with the type, capability, and the like of the work to be executed. In the configuration of Patent Document 1, a dedicated structure is established for each model or each specification such that two electric motors are disposed in a front portion of a transmission case, and a planetary gear mechanism, a forward/reverse switching gear mechanism, a sub-transmission gear mechanism, and the like are accommodated in the transmission case. That is, no consideration is given to commonality of members, easiness of development of variations, and the like. For this reason, the demand for cost reduction and effective use of resources, which has increased in recent years, is not met, and there is room for improvement.

Solution to Problem

[0007] It is a technical object of the present invention to provide an electric transmission and a work vehicle including an electric transmission improved by studying the current situation described above.

[0008] An electric transmission according to a first aspect of the present invention includes: a work electric motor; a travel electric motor; and a power combining mechanism that combines output of both of the electric motors, wherein, at least the output of the travel electric motor is variably controlled to change the output of the power combining mechanism, both of the electric motors and

the power combining mechanism are assembled in a common casing to form a unit, and the output of the work electric motor and the output of the power combining mechanism are respectively taken out from the casing.
[0009] In an electric transmission according to a second aspect of the present invention, a work-machine drive shaft to which the output of the work electric motor is transmitted and a travel drive shaft to which the output of the power combining mechanism is transmitted are supported in parallel by the casing and protrude outward in the same direction.
[0010] In an electric transmission according to a third aspect of the present invention, rated power output of the work electric motor is greater than rated power output of the travel electric motor.
[0011] In an electric transmission according to a fourth aspect of the present invention, the power combining mechanism is structured such that transmission output of the power combining mechanism is maximized when the output of the travel electric motor is maximized in one direction, and transmission output of the power combining mechanism is minimized or zero when the output of the travel electric motor is maximized in another direction.
[0012] A work vehicle according to a fifth aspect of the present invention includes the electric transmission according to any one of the first to fourth aspects, and a machine body frame. In this case, the electric transmission is structured to be supported on the machine body frame in a vibration-proof manner via a pair of vibration isolating members on at least right and left outer side portions of the casing.
Advantageous Effects of Invention
[0013] According to the present invention, both electric motors and a power combining mechanism are assembled to a common casing to form a unit, and the output of the work electric motor and the output of the power combining mechanism can be respectively taken out from a casing, so that both electric motors and the power combining mechanism can be easily assembled to a power transmission such as a transmission case as a single unit of an electric transmission. That is, the electric transmission can be shared among different models and specifications, and can be easily adapted to, for example, a plurality of models and specifications of a work vehicle only by developing variations of power transmissions such as the transmission case except for the electric transmission. Therefore, the assembling workability (assembling efficiency) can be improved, and the cost for developing variations can be reduced.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0014] FIG. **1** is an overall side view of an agricultural tractor according to a first embodiment.
[0015] FIG. **2** illustrates a power transmission system of the agricultural tractor.
[0016] FIG. **3** illustrates a power transmission system of an electric transmission.
[0017] FIG. **4** is a partially cutaway transverse cross-sectional view of the electric transmission.
[0018] FIG. **5** is an output characteristic diagram illustrating the relationship between the traveling speed of the agricultural tractor and the output of a travel electric motor.
[0019] FIG. **6** illustrates a power transmission system of an agricultural tractor according to a second embodiment.
[0020] FIG. **7** illustrates a power transmission system of an electric transmission.
[0021] FIG. **8** is a partially cutaway transverse cross-sectional view of the electric transmission.
[0022] FIG. **9** illustrates a power transmission system of an agricultural tractor according to a third embodiment.
[0023] FIG. **10** is a longitudinal cross-sectional view of a traveling machine body illustrating a support structure of an electric transmission.
[0024] FIG. **11** illustrates a power transmission system of an agricultural tractor according to a

fourth embodiment.
[0025] FIG. **12** illustrates a power transmission system of an electric transmission.
[0026] FIG. **13** is an output characteristic diagram illustrating the relationship between the traveling speed of the agricultural tractor and the output of a travel electric motor.

DESCRIPTION OF EMBODIMENTS

[0027] An electric transmission of an agricultural tractor for agricultural work (hereinafter, simply referred to as "agricultural tractor"), which is an example of a work vehicle, according to embodiments of the present invention is embodied will now be described with reference to the drawings (FIG. **1** to FIG. **13**). In the following description, the terms "front and rear," "left and right," and "up and down" are used to specify directions. These are defined with reference to the forward direction of a traveling machine body **1**. However, these terms are used for convenience of description and do not limit the technical scope of the present invention.
[0028] First, an outline of an agricultural tractor will be described with reference to FIG. **1** and FIG. **2**. As illustrated in FIG. **1** and FIG. **2**, a traveling machine body **1** of the agricultural tractor according to a first embodiment is supported by a pair of left and right front wheels **2** and a pair of left and right rear wheels **3**, which are traveling parts. A chargeable and dischargeable power supply device **4** (battery) formed of a secondary battery, a large-capacity capacitor, or the like, and a steering column **5** including a steering handle **6** are provided on a front portion of an upper surface of the traveling machine body **1**.
[0029] A steering seat **7** is disposed behind the steering handle **6**. When an operator seated on the steering seat **7** turns the steering handle **6**, the steering angle (operation angle) of the right and left front wheels **2** changes in accordance with the amount of turning operation. A machine body frame of the traveling machine body **1** has a monocoque structure, and a transmission case **8** accommodating the front wheels **2**, the rear wheels **3**, a gear transmission mechanism for transmitting a driving force to a ground work machine (not illustrated), and the like is mounted on a rear portion of the machine body frame. Reference numeral **9** denotes an electric transmission according to the present invention, which functions as a drive source of the front wheels **2**, the rear wheels **3**, and the ground work machine, as will be described later. The electric transmission **9** is mounted on a front surface of the transmission case **8**.
[0030] A hydraulic lifting mechanism **10** that lifts and lowers a ground work machine (not illustrated) such as a rotary tiller connected to a rear portion of the traveling machine body **1** is detachably attached to an upper surface of a rear portion of the transmission case **8**. The ground work machine is connected to the rear of the transmission case **8** via a three-point link mechanism **11**. A PTO shaft **12** that transmits a PTO driving force to the ground work machine is provided on a rear surface of the transmission case **8** so as to protrude rearward.
[0031] Next, a power transmission system of the agricultural tractor will be described with reference to FIG. **2** to FIG. **4**. The agricultural tractor of the first embodiment is structured such that the output from the electric transmission **9** is distributed to the front wheels **2**, the rear wheels **3**, and the PTO shaft **12**. In the first embodiment, the electric transmission **9**, which transmits a driving force to the front wheels **2**, the rear wheels **3**, and the ground work machine (not illustrated) is mounted on the front surface side of the transmission case **8**. As will be described later, the electric transmission **9** may be mounted on the machine body frame in a state where the electric transmission **9** is separated from the transmission case **8** and a power transmission state is maintained via a universal joint.
[0032] The electric transmission **9** includes a work electric motor **13** and a travel electric motor **14** as power sources, and a planetary gear mechanism **15** as a power combining mechanism that combines outputs of the electric motors **13** and **14**. The electric transmission **9** in this case is a unit in which the work electric motor **13**, the travel electric motor **14**, and the planetary gear mechanism **15** are assembled in a common casing **16**.
[0033] The electric transmission **9** has two paths: a power transmission path via a work motor shaft

17 and a work-machine drive shaft **39** projecting rearward from the work electric motor **13**, and a power transmission path via a travel drive shaft **19** extending rearward from the planetary gear mechanism **15**. That is, the output of the work electric motor **13** and the combined output (transmission output) of the planetary gear mechanism **15** are each taken out from the casing **16** to the outside and transmitted to the transmission case **8**.

[0034] The electric transmission **9** is formed such that a portion of the output via the work motor shaft **17** and the output via a travel motor shaft **18** are combined by the planetary gear mechanism **15**, and the front wheels **2** and the rear wheels **3** are rotationally driven by the combined output (transmission output) via the travel drive shaft **19** extending rearward from the planetary gear mechanism **15**. The electric transmission **9** is formed to rotationally drive the PTO shaft **12** only by the remaining output of the work electric motor **13** via the work motor shaft **17**. The travel motor shaft **18** protrudes rearward from the travel electric motor **14**.

[0035] In this case, the combined output of the planetary gear mechanism **15** can be shifted by changing and controlling at least the output rotation of the travel electric motor **14**. The work electric motor **13** of the first embodiment is formed to keep the output (rotational speed) substantially constant regardless of load fluctuation. The travel electric motor **14** of the first embodiment is formed such that the rotation direction can be reversed and the output rotation can be changed steplessly (continuously) from zero to a predetermined maximum speed.

[0036] In the first embodiment, the rated output of the work electric motor **13** is larger than the rated output of the travel electric motor **14**. In other words, the work electric motor **13** has a larger capacity than the travel electric motor **14**. A drive source (for example, an internal combustion engine) in a work vehicle such as an agricultural tractor needs to have a capability to be used for driving a work machine and a capability to be used for traveling drive. In order to cover these two capabilities with a single electric motor, a considerably large capacity is required, resulting in a high cost. According to the present invention, by setting the capacity of the work electric motor **13** having the ability to be used for driving a work machine such that the work electric motor **13** has a portion of the ability necessary for traveling drive, it is possible to provide a compact drive source with reduced cost as a whole.

[0037] The transmission case **8** disposed at the rear of the traveling machine body **1** accommodates a forward/reverse switching and sub-transmission gear mechanism **20** that switches the output via the travel drive shaft **19** to the forward or reverse direction and changes the speed, a rear axle mechanism **23** that transmits the output via the forward/reverse switching and sub-transmission gear mechanism **20** to the left and right rear wheels **3**, and a PTO transmission gear mechanism **21** that appropriately changes the speed of the output via the work motor shaft **17** and transmits the resulting output to the PTO shaft **12**. A front portion of the traveling machine body **1** is provided with a front axle mechanism **22** that transmits the power via the sub-transmission gear mechanism **20** to the left and right front wheels **2**.

[0038] The travel drive shaft **19** of the planetary gear mechanism **15** is interlockingly connected to a travel input shaft **24** protruding forward from the forward/reverse switching and sub-transmission gear mechanism **20**. A front-wheel output shaft **25** projects forward from the forward/reverse switching and sub-transmission gear mechanism **20**. The front-wheel output shaft **25** is interlockingly connected to the front axle mechanism **22** in a front portion of the traveling machine body **1** via a front-wheel drive clutch **26** and a front-wheel propeller shaft **27**. A travel output shaft **28** projects rearward from the forward/reverse switching and sub-transmission gear mechanism **20**. The travel output shaft **28** is interlockingly connected to the rear axle mechanism **23**.

[0039] The combined output transmitted from the travel drive shaft **19** of the planetary gear mechanism **15** to the forward/reverse switching and sub-transmission gear mechanism **20** is branched and transmitted to the front wheels **2** side and the rear wheels **3** side. The output directed to the front wheels **2** is transmitted from the front-wheel output shaft **25** of the forward/reverse switching and sub-transmission gear mechanism **20** to a front wheel drive shaft **29** rotatably

supporting the left and right front wheels **2** via the front-wheel drive clutch **26**, the front-wheel propeller shaft **27**, and the front axle mechanism **22**, thereby rotationally driving the left and right front wheels **2**. The output directed toward the rear wheels **3** is transmitted from a travel output shaft **28** of the forward/reverse switching and sub-transmission gear mechanism **20** to a rear wheel drive shaft **30** rotatably supporting the left and right rear wheels **3** via the rear axle mechanism **23**, thereby rotationally driving the left and right rear wheels **3**.

[0040] The work motor shaft **17** of the work electric motor **13** is interlockingly connected to the front portion side of a PTO transmission shaft **31** extending in the front-rear direction in the transmission case **8** via the work-machine drive shaft **39** described later. The rear portion side of the PTO transmission shaft **31** is interlockingly connected to a PTO input shaft **33** protruding forward from the PTO transmission gear mechanism **21** via a PTO clutch **32**. The PTO shaft **12** projects rearward from the PTO transmission gear mechanism **21** to the outside of the transmission case **8**. The output transmitted from the work motor shaft **17** of the work electric motor **13** to the PTO transmission shaft **31** is transmitted to the PTO transmission gear mechanism **21** via the PTO clutch **32** and the PTO input shaft **33** to rotationally drive the PTO shaft **12**.

[0041] Next, a detailed structure of the electric transmission **9** will be described with reference to FIG. **2** to FIG. **4**. As described above, the electric transmission **9** is a unit in which the work electric motor **13** and the travel electric motor **14**, which are power sources, and the planetary gear mechanism **15**, which is a power combining mechanism, are assembled in the common casing **16**. In the first embodiment, the casing **16** of the electric transmission **9** is composed of two shell-like members, i.e., a main body portion **34** that is deep and opens rearward, and a lid portion **35** that covers and closes the opening of the main body portion **34** and is shallower than the main body portion **34**. Although not illustrated, the main body portion **34** and the lid portion **35** are bolted together. Various shafts, gears, and the like are disposed inside the casing **16** in a state where the main body portion **34** is closed by the lid portion **35**.

[0042] The work electric motor **13** and the travel electric motor **14** are mounted on the front surface side of the main body portion **34** of the casing **16** so as to be arranged vertically. The work motor shaft **17** of the work electric motor **13** penetrates a front wall **36** of the main body portion **34**. The distal end side of the work motor shaft **17** protrudes into the casing **16**. The work motor shaft **17** is rotatably supported by the front wall **36** of the main body portion **34** via a sealed bearing **37**. Similarly, the travel motor shaft **18** of the travel electric motor **14** also passes through the front wall **36** of the main body portion **34**, and the distal end side thereof protrudes into the casing **16**. The travel motor shaft **18** is also rotatably supported by the front wall **36** of the main body portion **34** via a sealed bearing **38**.

[0043] The work-machine drive shaft **39** coaxially connected to the work motor shaft **17** is rotatably supported in an upper portion of the casing **16**. The distal end side of the work motor shaft **17** is spline-engaged with the proximal end side of the work-machine drive shaft **39** so as to be relatively non-rotatable. Therefore, the work-machine drive shaft **39** rotates integrally with the work motor shaft **17**. The work-machine drive shaft **39** penetrates through the lid portion **35**, and the distal end side thereof protrudes to the outside from the casing **16**. In the present invention, the term “work-machine drive shaft extending from the work electric motor **13**” is used as a broader concept of the work motor shaft **17** and/or the work-machine drive shaft **39**. An opening portion of the lid portion **35** through which the work-machine drive shaft **39** is inserted is closed by an annular seal **40** fitted on the work-machine drive shaft **39**. An output branching gear **41** is fixed to a longitudinally intermediate portion of the work-machine drive shaft **39**.

[0044] As illustrated in detail in FIG. **4**, an idle shaft **42** extending in parallel with the work-machine drive shaft **39** is rotatably supported at a vertically intermediate portion in the casing **16**. An idle gear **43** is fixed to a longitudinally intermediate portion of the idle shaft **42**. The output branching gear **41** of the work-machine drive shaft **39** is always engaged with the idle gear **43**. The idle shaft **42** is not illustrated in FIG. **2** and FIG. **3**.

[0045] The planetary gear mechanism **15** serving as a power combining mechanism is disposed in a lower portion of the casing **16**. The planetary gear mechanism **15** includes a sun gear **45** fixed to a sun gear shaft **44** coaxial with the travel motor shaft **18**, a hollow carrier **46** rotatably supporting a plurality of planetary gears **47** on the same radius, and a ring gear **48** having internal teeth on an inner circumferential surface thereof. The distal end side of the travel motor shaft **18** is inserted into the proximal end side of the sun gear shaft **44** so as not to be relatively rotatable. Therefore, the sun gear shaft **44** and the sun gear **45** rotate integrally with the travel motor shaft **18**. The sun gear **45** meshes with the respective planetary gears **47** of the carrier **46** from the radially inner side.
[0046] The carrier **46** is rotatably supported by the casing **16**. The sun gear shaft **44** is rotatably inserted into the carrier **46**. The travel drive shaft **19** is integrally provided on a portion of the carrier **46** on the side opposite to the travel motor shaft **18**. A front middle portion of the travel drive shaft **19** is rotatably supported by the lid portion **35**. The travel drive shaft **19** penetrates through the lid portion **35**, and the distal end side thereof protrudes to the outside from the casing **16**. The opening portion of the lid portion **35** through which the travel drive shaft **19** is inserted is closed by an annular seal **49** fitted to the travel drive shaft **19**.
[0047] The ring gear **48** is rotatably fitted on the travel drive shaft **19** extending from the carrier **46**. The internal teeth **50** on the inner circumferential surface of the ring gear **48** mesh with the respective planetary gears **47** of the carrier **46** from the radially outer side. A combining gear **51** that rotates integrally with the ring gear **48** is also rotatably supported on the travel drive shaft **19**. The combining gear **51** is constantly meshed with the idle gear **43**. That is, the output branching gear **41** of the work-machine drive shaft **39** can transmit power to the combining gear **51** via the idle gear **43**. In the first embodiment, the ring gear **48** and the combining gear **51** have an integral structure. The travel motor shaft **18**, the sun gear shaft **44**, the sun gear **45**, the carrier **46**, the ring gear **48**, the combining gear **51**, and the travel drive shaft **19** are all positioned coaxially.
[0048] As illustrated in FIG. **2** to FIG. **4**, the work-machine drive shaft **39** and the travel drive shaft **19** extending from the planetary gear mechanism **15** protrude from the casing **16** to the outside in the same direction (in the first embodiment, protrude rearward in parallel to each other). The distal end side (rear end side) of the work-machine drive shaft **39** is interlockingly connected to the PTO transmission shaft **31** of the transmission case **8**, and the distal end side (rear end side) of the travel drive shaft **19** is interlockingly connected to the travel input shaft **24** of the transmission case **8**.
[0049] When both the work electric motor **13** and the travel electric motor **14** are driven, the corresponding motor shafts **17** and **18** rotate. A portion of the output of the work motor shaft **17** is transmitted to the ring gear **48** via the output branching gear **41**, the idle gear **43**, and the combining gear **51** of the work-machine drive shaft **39**. The output of the travel motor shaft **18** is transmitted to the sun gear **45** of the sun gear shaft **44**. Since each planetary gear **47** is constantly meshed with both the internal teeth **50** of the ring gear **48** and the sun gear **45**, the output via the ring gear **48** and the output via the sun gear **45** are combined by the plurality of planetary gears **47** and transmitted to the carrier **46** and thus to the travel drive shaft **19**. The combined output (transmission output) transmitted to the travel drive shaft **19** is transmitted to the travel input shaft **24** of the transmission case **8**. The remaining output of the work motor shaft **17** is transmitted to the PTO transmission shaft **31** of the transmission case **8** via the work-machine drive shaft **39**.
[0050] According to the electric transmission **9** of the first embodiment, both electric motors **13** and **14** and the planetary gear mechanism **15** are assembled to a common casing **16** to form a unit, and the output of the work electric motor **13** and the combined output of the planetary gear mechanism **15** can be respectively taken out from the casing **16**, so that both electric motors **13** and **14** and the planetary gear mechanism **15** can be easily assembled to a power transmission such as a transmission case **8** as a single unit of the electric transmission **9**. That is, the electric transmission **9** can be shared among different models and specifications, and can be easily adapted to, for example, a plurality of models and specifications of agricultural tractors only by developing variations of power transmissions such as the transmission case **8** except for the electric

transmission **9**. Therefore, the efficiency of the assembling work can be improved, and the cost for developing variations can be reduced.

[0051] As described above in the first embodiment, the work electric motor **13** is structured to maintain the rotation speed (output) at the optimum predetermined rotation speed as the work rotation on one side in the rotation direction, regardless of the load fluctuation. On the other hand, the travel electric motor **14** is structured to be rotatable in forward and reverse directions and to be capable of steplessly (continuously) changing its output. FIG. **5** is an output characteristic diagram illustrated the relationship between the traveling speed of the agricultural tractor (which may be referred to as the combined output of the planetary gear mechanism **15**) and the output of the travel electric motor **14**. This is an example in a state in which the output (rotational speed) of the work electric motor **13** is held substantially constant regardless of load fluctuation. As can be seen from FIG. **5**, the planetary gear mechanism **15** is structured such that the combined output (transmission output) is maximized when the output of the travel electric motor **14** is maximized in one direction (here, maximized in the plus (+, positive) direction), and the combined output (transmission output) is minimized or zero when the output of the travel electric motor **14** is maximized in the other direction (here, maximized in the minus (−, reverse) direction).

[0052] Therefore, the output characteristics of the travel electric motor **14** can be used in a wide range from the maximum in one direction to the maximum in the other direction without being limited to a narrow range from zero to the maximum in one direction or the other direction. Even if the capacity of the travel electric motor **14** is not increased, it is possible to reliably achieve the expansion of the shiftable range using the power combining function of the planetary gear mechanism **15**, to reduce the weight and cost of the travel electric motor **14** and thus the electric transmission **9**, and to increase the output of the planetary gear mechanism **15**.

[0053] A tractor employing the electric transmission **9** of a second embodiment will now be described with reference to FIG. **6** to FIG. **8**. In the description of the second and subsequent embodiments, the same components as those of the first embodiment described above are denoted by the same reference numerals as those of the first embodiment, and the detailed description thereof will be omitted.

[0054] In the second embodiment, the work electric motor **13** and the travel electric motor **14** are separately disposed on the front and rear sides of the upper portion of the casing **16**. The work electric motor **13** is attached to the lid portion **35**, and the travel electric motor **14** is attached to the front wall **36** of the main body portion **34**. That is, the work electric motor **13** and the travel electric motor **14** are disposed in the casing **16** along the front-rear direction of the vehicle body.

[0055] The work motor shaft **17** protrudes from the base portion of the work electric motor **13** to both front and rear sides. The front end side of the work motor shaft **17** penetrates the lid portion **35** and protrudes into the casing **16**. The rear end side of the work motor shaft **17** protrudes from the base portion of the work electric motor **13** to the outside. Therefore, the work motor shaft **17** protrudes from the lid portion **35** of the casing **16** to the outside via the base portion of the work electric motor **13**. The rear end side of the work motor shaft **17** is interlockingly connected to the PTO transmission shaft **31** of the transmission case **8** via a work-power relay shaft **52** having universal joints at the front and rear. The front end side of the work motor shaft **17** is rotatably supported by the lid portion **35** via the sealed bearing **37**. The travel motor shaft **18** penetrates through the front wall **36** of the main body portion **34**, and the distal end side (rear end side) thereof protrudes into the casing **16**. The travel motor shaft **18** is rotatably supported by the front wall **36** of the main body portion **34** via a sealed bearing **38**.

[0056] The planetary gear mechanism **15** serving as a power combining mechanism is disposed in an upper portion of the casing **16**. The planetary gear mechanism **15** of the second embodiment includes the sun gear **45** fixed to the sun gear shaft **44** coaxially connected with the travel motor shaft **18**, the hollow carrier **46** rotatably supporting the plurality of planetary gears **47** on the same radius, and the ring gear **48** having internal teeth on an inner circumferential surface thereof. The

distal end side of the travel motor shaft **18** is inserted into the proximal end side of the sun gear shaft **44** so as not to be relatively rotatable. Therefore, the sun gear shaft **44** and the sun gear **45** rotate integrally with the travel motor shaft **18**. The sun gear **45** meshes with the respective planetary gears **47** of the carrier **46** from the radially inner side.

[0057] The front end side of the carrier **46** is rotatably supported by the front wall **36** of the main body portion **34**. The sun gear shaft **44** is rotatably inserted into the carrier **46**. The rear end side of the carrier **46** is rotatably supported by the ring gear **48**. The ring gear **48** is rotatably supported by the lid portion **35** via a bearing in a state of being interlockingly connected to the front end side of the work motor shaft **17**. The internal teeth **50** on the inner circumferential surface of the ring gear **48** mesh with the respective planetary gears **47** of the carrier **46** from the radially outer side. The output branching gear **41** is fitted on the front end side (a portion surrounding the sun gear shaft **44**) of the carrier **46** so as not to be relatively rotatable. In the second embodiment, the travel motor shaft **18**, the sun gear shaft **44**, the sun gear **45**, the carrier **46**, the ring gear **48**, and the output branching gear **41** are all positioned coaxially.

[0058] FIG. **6** and FIG. **7** do not illustrate the idle shaft **42** rotatably supported at a vertically intermediate portion in the casing **16**. FIG. **8** does not illustrate the idle shaft **42** and the idle gear **43** provided thereon.

[0059] The travel drive shaft **19** extending in parallel with the motor shafts **17** and **18** and the sun gear shaft **44** is rotatably supported in a lower portion of the casing **16**. The distal end side (rear end side) of the travel drive shaft **19** penetrates the lid portion **35** and protrudes to the outside from the casing **16**. The distal end side (rear end side) of the travel drive shaft **19** is interlockingly connected to the travel input shaft **24** of the transmission case **8** via a travel-power relay shaft **53** having universal joints at the front and rear. The opening portion of the lid portion **35** through which the travel drive shaft **19** is inserted is closed by the annular seal **49** fitted to the travel drive shaft **19**. The combining gear **51** is fitted on the travel drive shaft **19** so as not to be relatively rotatable. The output branching gear **41** of the carrier **46** always meshes with the idle gear **43** (not illustrated), and similarly, the combining gear **51** also always meshes with the idle gear **43**. That is, the output branching gear **41** of the carrier **46** can transmit power to the combining gear **51** via the idle gear **43**.

[0060] As illustrated in FIG. **6** to FIG. **8**, the work motor shaft **17** constituting the work-machine drive shaft and the travel drive shaft **19** to which the output of the planetary gear mechanism **15** is transmitted protrude from the casing **16** to the outside in the same direction (also, in the second embodiment, protrude rearward in parallel to each other).

[0061] When both the work electric motor **13** and the travel electric motor **14** are driven, the respective motor shafts **17** and **18** are rotated. A portion of the output of the work motor shaft **17** is transmitted from the front end side thereof to the ring gear **48**. The output of the travel motor shaft **18** is transmitted to the sun gear **45** of the sun gear shaft **44**. Since each planetary gear **47** always meshes with both the internal teeth **50** of the ring gear **48** and the sun gear **45**, the output via the ring gear **48** and the output via the sun gear **45** are combined by the plurality of planetary gears **47** and transmitted from the carrier **46** to the travel drive shaft **19** via the output branching gear **41**, the idle gear **43**, and the combining gear **51**. The combined output (transmission output) transmitted to the travel drive shaft **19** is transmitted to the travel input shaft **24** of the transmission case **8**. The remaining output of the work motor shaft **17** is transmitted from the rear end side thereof to the PTO transmission shaft **31** of the transmission case **8**.

[0062] Also, in the case of the configuration as in the second embodiment, the electric transmission **9** can be shared between different models or specifications, and can be easily adapted to, for example, a plurality of models or specifications of agricultural tractors only by developing variations of the power transmission such as the transmission case **8** except for the electric transmission **9**. That is, it is possible to provide the electric transmission **9** similar to that of the first embodiment, which can improve the assembling workability (assembling efficiency) and can

reduce the cost for developing variations.
[0063] An agricultural tractor employing the electric transmission **9** of a third embodiment will now be described with reference to FIGS. **9** and **10**. The electric transmission **9** of the third embodiment basically has the same configuration as that of the first embodiment. However, in the third embodiment, the distal end side (rear end side) of the work-machine drive shaft **39** is interlockingly connected to the PTO transmission shaft **31** of the transmission case **8** via the work-power relay shaft **52** and is interlockingly connected to the travel input shaft **24** of the transmission case **8** via the travel-power relay shaft **53** of the travel drive shaft **19**.
[0064] As illustrated in FIG. **10**, in the third embodiment, the agricultural tractor includes a pair of right and left machine body frames **54** constituting the traveling machine body **1**. The electric transmission **9** is provided with a pair of vibration isolating members at least on the right and left outer sides of the casing **16**. The electric transmission **9** can be supported on the machine body frames **54** in a vibration-proof manner via a pair of vibration isolating members. In this case, the pair of left and right machine body frames **54** are provided with machine body brackets **55** protruding outward in the left-right direction in an intermediate portion in the front-rear direction. The electric transmission **9** is elastically supported by the pair of right and left machine body brackets **55** via a vibration isolating rubber **58** serving as a vibration isolating member.
[0065] The machine body brackets **55** are respectively fixed to the right and left outer surface sides of the corresponding machine body frames **54** by welding or the like. A nut **56** is fixed to the lower surface side of the machine body bracket **55** by welding or the like. A case receiving plate **57** corresponding to the machine body bracket **55** is bolted to both right and left outer wall surfaces of the casing **16** in the electric transmission **9**. The vibration isolating rubber **58** is arranged between the case receiving plate **57** and the machine body bracket **55** opposed to each other, and a bolt **59** passing through the case receiving plate **57** and the vibration isolating rubber **58** is screwed into the nut **56** on the machine body bracket **55** side, so that the case receiving plate **57** and the machine body bracket **55** sandwich the vibration isolating rubber **58**. As a result, the electric transmission **9** is elastically supported by the machine body frames **54** and the traveling machine body **1** via the pair of left and right vibration isolating rubber **58**.
[0066] According to the configuration of the third embodiment, since the electric transmission **9** is supported in a vibration-proof manner relative to the machine body frames **54** and the traveling machine body **1**, it is possible to suppress the propagation of vibration from the ground during traveling to the electric transmission **9**, and it is possible to provide the electric transmission **9** having excellent durability by reducing problems such as failure of the electric transmission **9** due to vibration.
[0067] A tractor employing the electric transmission **9** according to a fourth embodiment will now be described with reference to FIG. **11** to FIG. **13**. The electric transmission **9** of the fourth embodiment is basically the same as that of the first embodiment. However, the planetary gear mechanism **15** of the fourth embodiment includes two sun gears **65** and **70** and a plurality of double planetary gears **67**.
[0068] That is, the planetary gear mechanism **15** of the fourth embodiment includes a first sun gear **65** fixed to a first sun gear shaft **64** that is coaxial with and rotates integrally with the travel motor shaft **18**, a second sun gear shaft **69** disposed coaxially with and relatively rotatably with respect to the travel motor shaft **18** and the first sun gear shaft **64**, a second sun gear **70** fixed to the second sun gear shaft **69**, the double planetary gears **67** (**67***a* and **67***b*), a carrier **66** having the double planetary gears **67** axially supported on the same rotation locus, a ring gear **68** including internal teeth **73** on an inner circumferential surface, a low-speed clutch **71**, a high-speed clutch **72**, and a clutch switching control device.
[0069] The first sun gear **65** meshes with the first planetary gear **67***a* of the double planetary gears **67** from the radially inner side. The second sun gear **70** meshes with the second planetary gear **67***b* of the double planetary gears **67** from the radially inner side. The second sun gear shaft **69** is

connected to the travel drive shaft **19** extending rearward from the planetary gear mechanism **15** via the low-speed clutch **71** so that power can be connected and disconnected.

[0070] The carrier **66** is rotatably fitted on the second sun gear shaft **69**. The carrier **66** is connected to the travel drive shaft **19** via the high-speed clutch **72** so that power can be connected and disconnected. The internal teeth **73** of the ring gear **68** mesh with the first planetary gear **67***a* of the double planetary gears **67** from the outside in the radial direction. The ring gear **68** and the combining gear **51** that rotates integrally with the ring gear **68** are rotatably fitted on the first sun gear shaft **64**.

[0071] The work-machine drive shaft **39** outputs a predetermined constant rotation toward the outside. The output branching gear **41** located in the casing **16** can transmit the constant rotation of the work electric motor **13** to the combining gear **51** via the idle gear **43**. In the fourth embodiment, the ring gear **68** and the combining gear **51** have an integral structure. The travel motor shaft **18**, the first sun gear shaft **64**, the first sun gear **65**, the second sun gear **70**, the second sun gear shaft **69**, the carrier **66**, the ring gear **68**, the combining gear **51**, and the travel drive shaft **19** are all positioned coaxially.

[0072] FIG. **13** is an output characteristic diagram illustrated the relationship between the traveling speed of the agricultural tractor (combined output of the planetary gear mechanism **15**) according to the fourth embodiment and the output of the travel electric motor **14**. The output characteristic diagram is an example in a state in which the work electric motor **13** is controlled so as to output a constant rotational speed corresponding to an appropriate speed of the work machine regardless of the load fluctuation. In order to obtain this characteristic, the control device is provided with various sensors for shift operation signals and traveling speed.

[0073] In the planetary gear mechanism **15** of the fourth embodiment, in a state where the low-speed clutch **71** is engaged, the combined output (transmission output) is minimum or zero when the output of the travel electric motor **14** is maximum in the other direction (here, the minus (−, reverse) direction). As the speed of the travel electric motor **14** increases in one direction (here, the plus (+, positive) direction), the rotation of the carrier **66** is multiplied by the gear ratio of the gears **67***b* and **70** and transmitted to the second sun gear **70** through the revolution and rotation of the second planetary gears **67***b*, and the output speed of the travel drive shaft **19** in increased by the second sun gear shaft **69**.

[0074] The clutch to be connected is switched from the low-speed clutch **71** to the high-speed clutch **72** at the time when the speed becomes substantially maximum (at a point indicated as “clutch switching” in FIG. **13**). Then, the power transmission from the second sun gear shaft **69** to the travel drive shaft **19** is cut off, and the power from the carrier **66** is transmitted to the travel drive shaft **19**. The rotation of the carrier **66** is transmitted to the travel drive shaft **19** without passing through the gear ratio of the gears **67***b* and **70**. Next, as the output of the travel electric motor **14** becomes the maximum in the other direction (here, the minus (−, reverse) direction), the combined output (transmission output) increases, and when the output of the travel electric motor **14** becomes the maximum in the other direction (here, the minus (−, reverse) direction), the output speed of the travel drive shaft **19** becomes the maximum. The gear ratios (parameters) of each gear are designed so that the speed can be synchronized before and after the clutch is switched.

[0075] Therefore, in the fourth embodiment, as compared with the first to third embodiments, a wider range can be achieved by output division, and the shiftable range using the planetary gear mechanism **15** can be further expanded.

[0076] The configurations of the above-described embodiments are not limited to those illustrated in the drawings, and various modifications can be made without departing from the spirit of the present invention. For example, the electric transmission of the present invention can be applied not only to agricultural work machines (such as combines and tractors) but also to construction machines (such as hydraulic excavators and forklifts).

REFERENCE SIGNS LIST

[0077] **8** transmission case [0078] **9** electric transmission [0079] **12** PTO shaft [0080] **13** work electric motor [0081] **14** travel electric motor [0082] **15** planetary gear mechanism (power combining mechanism) [0083] **16** casing [0084] **17** work motor shaft [0085] **18** travel motor shaft [0086] **19** travel drive shaft [0087] **34** main body portion [0088] **35** lid portion [0089] **36** front wall [0090] **39** work-machine drive shaft [0091] **41** output branching gear [0092] **43** idle gear [0093] **45** sun gear [0094] **46** carrier [0095] **47** planetary gear [0096] **48** ring gear [0097] **50** internal teeth [0098] **51** combining gear

Claims

1. An electric transmission comprising: a work electric motor; a travel electric motor; and a power combining mechanism that combines output of both of the electric motors, wherein, at least the output of the travel electric motor is variably controlled to change the output of the power combining mechanism, both of the electric motors and the power combining mechanism are assembled in a common casing to form a unit, and the output of the work electric motor and the output of the power combining mechanism are respectively taken out from the casing.
2. The electric transmission according to claim 1, wherein a work-machine drive shaft to which the output of the work electric motor is transmitted and a travel drive shaft to which the output of the power combining mechanism is transmitted are supported in parallel by the casing and protrude outward in a same direction.
3. The electric transmission according to claim 1, wherein rated power output of the work electric motor is greater than rated power output of the travel electric motor.
4. The electric transmission according to claim 1, wherein the power combining mechanism is structured such that transmission output of the power combining mechanism is maximized when the output of the travel electric motor is maximized in one direction, and transmission output of the power combining mechanism is minimized or zero when the output of the travel electric motor is maximized in another direction.
5. A work vehicle comprising: the electric transmission according claim 1; and a machine body frame, wherein the electric transmission is structured to be supported on the machine body frame in a vibration-proof manner via a pair of vibration isolating members on at least right and left outer side portions of the casing.