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(54)

A METHOD FOR OPERATING A WORKING MACHINE, A WORKING MACHINE AND A CONTROLLER

- (57) The invention relates to a method for operating a working machine with working hydraulics comprising a pump, the working machine further comprising an independent motor drive for powering the working hydraulics comprising the steps estimating a load on the working hydraulics based on a load estimation model using an actual motor power consumption of the independent motor drive, comparing the estimated load with a critical threshold, if the estimated load is above the critical threshold providing a warning signal or a control command stopping an actual movement.

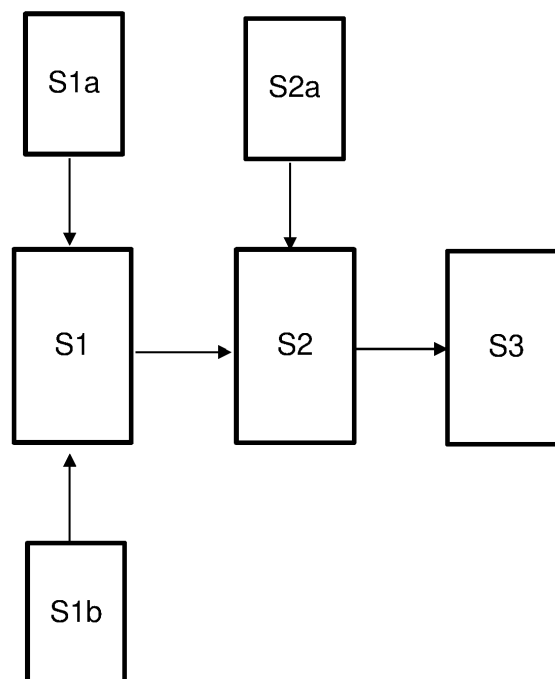


Fig. 1

Description

TECHNICAL FIELD

5 [0001] The disclosure relates generally to working machines. In particular aspects, the disclosure relates to working machines with working hydraulics, especially construction machines with working hydraulics. Although the disclosure may be described with respect to a particular vehicle, the disclosure is not restricted to any particular vehicle.

BACKGROUND

10 [0002] During operation of a working machine like for example a wheel loader, it is possible that sometimes the bucket or the forks are overloaded. This can lead to dangerous situations like losing control of the machine or the machine tipping over during operation.

SUMMARY

[0003] An object of the invention is to provide a method for operating a working machine with enhanced safety without additional sensors.

20 [0004] According to a first aspect of the disclosure, this is achieved by a method for operating a working machine with working hydraulics comprising a pump, the working machine further comprising an independent motor drive for powering the working hydraulics comprising the steps

- estimating a load on the working hydraulics based on a load estimation model using an actual motor power consumption of the independent motor drive,
- 25 - comparing the estimated load with a critical threshold,
- if the estimated load is above the critical threshold providing a warning signal or a control command stopping an actual movement.

30 [0005] The first aspect of the disclosure may seek to enhance safety by avoid overload situations and especially dangerous conditions for the working machine. A technical benefit includes that with the invention there is no need for additional pressure sensors as in existing solutions while safety is nevertheless enhanced. The invention allows for working machines without pressure sensors to measure the weight on the working hydraulics. Instead of such pressure sensors the invention uses information related to the power consumption of the independent motor drive of the working hydraulics, which are already available as part of the communication between the machine and an inverter controlling the working hydraulic motor.

35 [0006] The invention makes use of the independent motor drive for powering the working hydraulics as this means that the power consumption of the motor is an indication for the weight of the load that is put on the working hydraulics of the machine. Therefore, the load on the working hydraulics can be estimated without the use of additional pressure measurement sensors on the machine. Thus the invention is especially useful for working machines having an independent motor drive, such as for example an electric compact wheel loader.

40 [0007] Since the weight measurement according to the invention is an estimation based on existing sensors inside the machine, the cost can be reduced while providing enhanced safety as costs for additional sensors with weight measurement function are no more needed.

45 [0008] If an overload situation is detected either a warning signal can be provided, which alarms the driver or in an automatic solution a control command can be provided for example to either the central controller of the working machine or a controller of the working hydraulics to stop an actual movement, for example to stop driving or to stop further lifting of the a working attachment such as a fork or bucket.

50 [0009] Optionally in some examples, including in at least one preferred example, the critical threshold is determined using information on orientation of the working machine and/or of the working hydraulics, wherein information on orientation is preferably provided using inertial measurement units on the working machine and/or information on a speed of the working machine. A technical benefit may include that taking into account an actual orientation or speed when determining a critical threshold allows for a more accurate determination, at which point a load is critical. For example if the working machine itself is already in imbalance or travels at higher speed the critical threshold should be lower than in a stable position or with lower speed. In at least one preferred example the information on orientation comprises boom, bucket and/or vehicle orientation.

55 [0010] According to a further embodiment the load estimation model uses a pump flow rate Q delivered by the pump together with a motor speed ω and/or a current I and a voltage V of the independent motor drive to determine the estimated load. It is thereby preferred that the pump flow rate Q is estimated using a known volume of the pump $V_{o_{\text{pump}}}$ and a

rotational speed of the pump n , wherein preferably the pump flow rate is estimated according to $Q = V_{o_{\text{pump}}} \cdot n$, wherein

- n is the rotational speed of the pump in rad/s and
- $V_{o_{\text{pump}}}$ is the volume of the pump in m^3 .

[0011] Optionally in some examples, including in at least one preferred example the load estimation modul determines the estimated load using $F/A = (T \cdot \omega / \eta V_o) \cdot t$ or

$$F/A = (V \cdot I / V_o) \cdot t,$$

wherein

- F is force in N,
- T is torque in Nm,
- ω is motor speed in rad/s,
- η is efficiency of the independent motor drive,
- V_o is total volume delivered by the pump in m^3 and $V_o = \int Q \, dt$,
- Q is working pump flow rate in m^3/s
- V is voltage in V,
- I is current in A,
- A is area over which force is applied in m^2 ,
- t is time in s.

[0012] Thus the load as F/A or the force F on the working hydraulics is estimated using either known parameters or parameters, which are already present or measured for controlling the working function of the working hydraulics.

[0013] Optionally in some examples, including in at least one preferred example the load estimation model additionally uses working hydraulic oil temperature. Using the working hydraulic oil temperature may improve accuracy of the estimation as the oil temperature influences the viscosity and as such also the working pump flow rate. In preferred embodiments based on the working hydraulic oil temperature a viscosity correction factor K_v is determined and based on the viscosity correction factor a corrected pump flow rate Q_c is determined according to $Q_c = K_v \cdot Q_0$, wherein Q_0 is a standard pump flow rate at a defined standard temperature and wherein the corrected flow rate is used by the load estimation modul as the pump flow rate.

[0014] Optionally in some examples, including in at least one preferred example values for the viscosity correction factor K_v for different temperatures are determined using stored values, which are preferably determined in a previous step according to $K_v = \mu / \mu_0$, wherein

- K_v is the viscosity correction factor,
- μ is the actual viscosity in $\text{Pa} \cdot \text{s}$ at a certain temperature,
- μ_0 is the reference viscosity at a standard temperature in $\text{Pa} \cdot \text{s}$.

[0015] According to a second aspect of the disclosure, the invention relates to a computer system for operating a working machine the computer system comprising a processing circuitry configured to perform the steps of the method according to the first aspect of the invention. The second aspect of the disclosure may seek to enhance safety by avoid overload situations and especially dangerous conditions for the working machine. A technical benefit includes that with the invention there is no need for additional pressure sensors as in existing solutions while safety is nevertheless enhanced.

[0016] According to a third aspect of the disclosure, the invention relates to a computer program comprising program code means for performing the steps of the method according to the first aspect of the invention when said program is executed by a processor device. The third aspect of the disclosure may seek to enhance safety by avoid overload situations and especially dangerous conditions for the working machine. A technical benefit includes that with the invention there is no need for additional pressure sensors as in existing solutions while safety is nevertheless enhanced.

[0017] According to a forth aspect of the disclosure, the invention relates to a non-transitory computer-readable storage medium comprising instructions, which when executed by the processor device, causes the processor device to perform the method according to the first aspect of the invention. The fourth aspect of the disclosure may seek to enhance safety by avoid overload situations and especially dangerous conditions for the working machine. A technical benefit includes that with the invention there is no need for additional pressure sensors as in existing solutions while safety is nevertheless enhanced.

[0018] According to a fifth aspect of the disclosure, the invention relates to working machine with working hydraulics and

an independent motor drive for powering the working hydraulics comprising a computer system according to the second aspect of the disclosure. The fifth aspect of the disclosure may seek to enhance safety by avoid overload situations and especially dangerous conditions for the working machine. A technical benefit includes that with the invention there is no need for additional pressure sensors as in existing solutions while safety is nevertheless enhanced.

[0019] Optionally in some examples, including in at least one preferred example the working machine is a wheel loader, preferably an electric compact wheel loader.

[0020] The disclosed aspects, examples (including any preferred examples), and/or accompanying claims may be suitably combined with each other as would be apparent to anyone of ordinary skill in the art. Additional features and advantages are disclosed in the following description, claims, and drawings, and in part will be readily apparent therefrom to those skilled in the art or recognized by practicing the disclosure as described herein.

[0021] There are also disclosed herein computer systems, control units, code modules, computer-implemented methods, computer readable media, and computer program products associated with the above discussed technical benefits.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Examples are described in more detail below with reference to the appended drawings.

FIG. 1 is a block diagram of a method for operating a working machine according to one example.

FIG. 2 is an exemplary schematic view of parts of a working machine according to the fifth aspect of the invention.

DETAILED DESCRIPTION

[0023] The detailed description set forth below provides information and examples of the disclosed technology with sufficient detail to enable those skilled in the art to practice the disclosure.

[0024] FIG. 1 is a block diagram of a method for operating a working machine according to one example.

[0025] The method for operating a working machine with working hydraulics comprising a pump, the working machine further comprising an independent motor drive for powering the working hydraulics comprising the following steps. In step S1 a load on the working hydraulics is estimated based on a load estimation model using an actual motor power consumption of the independent motor drive. In step S2 the estimated load is compared with a critical threshold and in step S3 a warning signal or a control command stopping an actual movement is provided if the estimated load is above the critical threshold.

[0026] As the working machine picks up load with a fork or a bucket, an increase in the power consumed by the electric motor powering the working hydraulics can be seen. This relationship between the weight of the load picked up and the power consumed by the motor is according to the invention used to estimate the weight of the load, respectively the load on the working hydraulics. Thus this inventions allows to work without need of any direct measurement of the load on the working hydraulics for example using pressure sensors. A

[0027] The load estimation is done with the help of the load estimation model, which determine the load using already present information on the motor power consumption and this load is then brought in relation to a threshold and the output of the comparison of load and critical threshold is then used to determine if a warning sign or an automated reaction is necessary. The load estimation model could also use a machine learning based approach to estimate the weight of the load.

[0028] Preferably the critical threshold is determined in step S2a using information on orientation of the working machine and/or of the working hydraulics and/or information on a speed of the working machine, wherein information on orientation is preferably provided using inertial measurement units on the working machine. Information on the speed of the working machine itself may be provided by for example a central processing unit. The information on orientation may in some examples comprise boom, bucket and/or vehicle orientation. By taking into account orientation of working machine and/or working hydraulics for determining the critical threshold the warning sign or automated action can be initiated more precisely reflecting the actual situation of the working machine. For example if the load is estimated close to a full load capacity of the machine and if the boom of the machine is lifted then driving the machine in such a position could be dangerous and likely cause the machine to tip over. So in this case a visual warning can be provided to the operator indicating that the machine is approaching unstable conditions. A fixed critical threshold independent of these parameters may nevertheless be used, but has to be much lower for avoiding a critical status of the working machine in all reasonable scenarios than a critical threshold which is determined taking into account the real actual situation or position of the working machine.

[0029] Preferably the load estimation model uses a pump flow rate Q delivered by the pump together with a motor speed ω and/or a current I and a voltage V of the independent motor drive to determine the estimated load. While motor speed, current and voltage can be received directly from the independent motor drive, respectively its control system, the pump

flow rate Q may be estimated using a known volume of the pump $V_{o_{\text{pump}}}$ and a rotational speed of the pump n, wherein preferably the pump flow rate is estimated according to $Q = V_{o_{\text{pump}}} \cdot n$, wherein n is the rotational speed of the pump in rad/s and $V_{o_{\text{pump}}}$ is the volume of the pump in m^3 in S1a and subsequently used in S1.

[0030] Preferably the load estimation modul determines the estimated load using $F/A =$

$$(T \cdot \omega / \eta V_o) \cdot t \quad \text{or} \quad F/A = (V \cdot I / V_o) \cdot t,$$

wherein

F is force in N,
T is torque in Nm,
 ω is motor speed in rad/s,
 η is efficiency of the independent motor drive,
Vo is total volume delivered by the pump in m^3 and $V_o = \int Q \, dt$,
Q is working pump flow rate in m^3/s
V is voltage in V,
I is current in A,
A is area over which force is applied in m^2 ,
t is time in s.

[0031] This estimation is based on the following recognitions, which are part of this invention:

[0032] The energy equation for a hydraulic system can be expressed in terms of pump flow rate Q and pump pressure P taking into account the following. The power W is the rate of doing work, and the energy E can be obtained by integrating power with respect to time according to $E = \int W \, dt$. In the case of a hydraulic system, the energy equation can thus be written as:

[0033] The power W in a hydraulic system is given by the product of pressure P and flow rate Q:

$$W = P \cdot Q \quad \text{thus} \quad E = \int (P \cdot Q) \, dt$$

[0034] Assuming that pressure P is constant over time:

$$E = P \cdot \int Q \, dt$$

[0035] The integral of flow rate with respect to time is the total volume Vo delivered by the pump:

$$E = P \cdot V_o \dots\dots\dots(1)$$

[0036] This equation expresses the energy transferred by the hydraulic system in terms of the pressure exerted by the pump and the total volume of fluid delivered.

[0037] On the other hand the energy consumed by an electric motor from the energy storage system can be calculated using the power formula and the time the motor is running. The formula for power W is:

$$W = V \cdot I \dots\dots\dots(2)$$

where:

- W is power in W,
- V is voltage in V,
- I is current in A.

[0038] The energy E consumed by the motor is given by:

$$E = V \cdot I \cdot t \dots\dots\dots(3)$$

where:

- E is energy in Ws or J,
- W is power in W,
- t is time in s.

[0039] The energy of the electric motor when its running can further be calculated with the basic equation for power

$$W = T \cdot \omega / \eta \quad (4)$$

where:

- W is power in W,
- T is torque in Nm,
- ω is motor speed in rad/s,
- η is the efficiency of the independent motor drive (as a decimal).

[0040] By equating (4) and (2) we can calculate the efficiency of the motor

$$\eta = T \cdot \omega / V \cdot I \quad (5)$$

[0041] The torque T of the motor can be obtained from the torque curves provided by the supplier of the electric motor.

[0042] To calculate the energy E consumed by the motor over time t, the expression for power W (4) can be brought into the energy formula $E = W \cdot t$:

$$E = (T \cdot \omega / \eta) \cdot t \quad (6)$$

[0043] Now with equating (6) and (1) we can estimate the pressure as

$$P = T \cdot \omega \cdot t / \eta V_0 \quad \text{or pressure per unit time } P/t = (T \cdot \omega / \eta V_0) \quad (7)$$

[0044] The pressure in a hydraulic system is related to the force applied and the area over which that force is distributed. The fundamental relationship is given by Pascal's Law, which states that any change in pressure applied at any point in an enclosed fluid is transmitted undiminished throughout the fluid in all directions.

[0045] The formula relating pressure P, force F, and area A in a hydraulic system is:

$$P = F \cdot A$$

where:

- P is pressure in N/m^2 ,
- F is force in N,
- A is area over which the force is applied in m^2 .

[0046] The area depends on the hardware used on the machine, for example on the working hydraulic cylinder that is powering the bucket. The area is in this case the area of the ends of the cylinder on which force is applied.

[0047] Rearranging this formula to solve for force or the load, results in:

$$F = P \cdot A$$

[0048] Using equation (7) the force is then

$$F = (T \cdot \omega / \eta V_0) \cdot t \cdot A,$$

[0049] Taking into account equation (5) the force can also be expressed as

$$F = (V \cdot I / V_0) \cdot A \cdot t.$$

[0050] Thus the load can be estimated using $F/A = (T \cdot \omega / \eta V_0) \cdot t$ or $F/A = (V \cdot I / V_0) \cdot t$. Thus force or load can be estimated in the load estimation model using parameters known or already available in the control system of the working hydraulics or the working machine, like voltage, current, total volume via flow rate (preferably via $V_0 = \int V_{\text{pump}} \cdot dt$) or via motor speed and efficiency and torque.

[0051] In addition to this the model accuracy can be significantly increased the load estimation model additionally uses working hydraulic oil temperature. Hydraulic oil viscosity is highly temperature-dependent. As the oil temperature increases, its viscosity typically decreases. This change in viscosity can affect the flow rate Q . Thus preferably in step S1b based on the working hydraulic oil temperature a viscosity correction factor K_v is determined and based on the viscosity correction factor a corrected pump flow rate Q_c is determined according $Q_c = K_v \cdot Q_0$, wherein Q_0 is a standard pump flow rate at a defined standard temperature. This corrected flow rate is used the subsequently used by the load estimation modul as the pump flow rate in step S1.

[0052] Preferably values for the viscosity correction factor K_v for different temperatures are determined using stored values, which are preferably determined in a previous step according to $K_v = \mu / \mu_0$, wherein

K_v is the viscosity correction factor,

μ is the actual viscosity in Pa·s at a certain temperature,

μ_0 is the reference viscosity at a standard temperature in Pa·s.

[0053] FIG. 2 is an exemplary schematic view of parts of a working machine according to the fifth aspect of the invention.

[0054] The working machine comprises working hydraulics (not shown) and an independent motor drive M for powering the working hydraulics via a pump P. Furthermore the working machine comprises a computer system according to the second aspect of the disclosure, which comprises a processing circuitry configured to perform the steps of the method according to first aspect of the invention. The processing circuitry is configured to estimate a load on the working hydraulics based on a load estimation model 100 using an actual motor power consumption of the independent motor drive, compare the estimated load with a critical threshold and if the estimated load is above the critical threshold provide a warning signal WS or a control command stopping an actual movement.

[0055] For this purpose the load estimation model 100 uses information on the power consumption 120 of the independent motor M, preferably voltage and current or torque and efficiency to estimate the load. The independent motor M drives in this example a working hydraulics pump P. A control system C of the working hydraulics further provides information on a flow rate 130 of the pump, respectively on a total volume delivered by the pump for load estimation model 100. With the information on power consumption 120 and information on the flow rate 130 the load can be estimated according to the load estimation modul with data already present in actual working machines without the use of additional sensors. The load can be preferably estimated using $F/A = (T \cdot \omega / \eta V_0) \cdot t$ or $F/A = (V \cdot I / V_0) \cdot t$ with

- F is force in N,
- T is torque in Nm,
- ω is motor speed in rad/s,
- η is efficiency of the independent motor drive,
- V_0 is total volume delivered by the pump in m^3 and $V_0 = \int Q \, dt$,
- Q is working pump flow rate in m^3/s
- V is voltage in V,
- I is current in A,
- A is area over which force is applied in m^2 ,
- t is time in s.

[0056] Furthermore in the shown example the central processing unit CPU provides information on an actual speed 140 of the working machine. Instead or additional inertial measurement units IMU on the working machine, for example on boom, bucket or vehicle may provide information on orientation 110. With information on actual speed 140 and/or information on orientation the critical threshold can be adapted to the actual situation of the working machine and a warning signal WS can be provided to the operator more precisely.

[0057] In order to determine the load more precisely additional information on a working hydraulic oil temperature 150 can be provided by the control system C of the working hydraulics for the load estimation model 100. By taking into account the working hydraulic oil temperature 150 when determining the flow rate a corrected flow rate, corrected by a correction factor $K_v = \mu / \mu_0$, wherein K_v is the viscosity correction factor, μ is the actual viscosity in Pa·s at a certain temperature, μ_0 is the reference viscosity at a standard temperature in Pa·s.

[0058] The computer system is adapted to execute instructions from a computer-readable medium to perform these and/or any of the functions or processing described herein. The computer system may be connected (e.g., networked) to other machines in a LAN (Local Area Network), LIN (Local Interconnect Network), automotive network communication protocol (e.g., FlexRay), an intranet, an extranet, or the Internet. The computer system may include any collection of devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. Accordingly, any reference in the disclosure and/or claims to a computer system, computing system, computer device, computing device, control system, control unit, electronic control unit (ECU), processor device, processing circuitry, etc., includes reference to one or more such devices to individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. For example, control system may include a single control unit or a plurality of control units connected or otherwise communicatively coupled to each other, such that any performed function may be distributed between the control units as desired. Further, such devices may communicate with each other or other devices by various system architectures, such as directly or via a Controller Area Network (CAN) bus, etc.

[0059] The operational actions described in any of the exemplary aspects herein are described to provide examples and discussion. The actions may be performed by hardware components, may be embodied in machine-executable instructions to cause a processor to perform the actions, or may be performed by a combination of hardware and software. Although a specific order of method actions may be shown or described, the order of the actions may differ. In addition, two or more actions may be performed concurrently or with partial concurrence.

[0060] The terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein specify the presence of stated features, integers, actions, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, actions, steps, operations, elements, components, and/or groups thereof.

[0061] It will be understood that, although the terms first, second, etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element without departing from the scope of the present disclosure.

[0062] Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element to another element as illustrated in the Figures. It will be understood that these terms and those discussed above are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.

[0063] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0064] It is to be understood that the present disclosure is not limited to the aspects described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the present disclosure and appended claims. In the drawings and specification, there have been disclosed aspects for purposes of illustration only and not for purposes of limitation, the scope of the disclosure being set forth in the following claims.

Claims

1. A method for operating a working machine with working hydraulics comprising a pump, the working machine further comprising an independent motor drive for powering the working hydraulics comprising the steps

- estimating a load on the working hydraulics based on a load estimation model using an actual motor power consumption of the independent motor drive,
- comparing the estimated load with a critical threshold,
- if the estimated load is above the critical threshold providing a warning signal or a control command stopping an actual movement.

2. The method according to claim 1, wherein the critical threshold is determined using information on orientation of the working machine and/or of the working hydraulics and/or information on a speed of the working machine, wherein information on orientation is preferably provided using inertial measurement units on the working machine.
- 5 3. The method according to claim 2, wherein the information on orientation comprises boom, bucket and/or vehicle orientation.
4. The method according to one of the precedent claims, wherein the load estimation model uses a pump flow rate (Q) delivered by the pump together with a motor speed (ω) and/or a current (I) and a voltage (V) of the independent motor drive to determine the estimated load.
- 10 5. The method according to claim 4, wherein the pump flow rate (Q) is estimated using a known volume of the pump (V_{o_pump}) and a rotational speed of the pump (n), wherein preferably the pump flow rate is estimated according to $Q = V_{o_pump} \cdot n$, wherein
 - n is the rotational speed of the pump in rad/s and
 - V_{o_pump} is the volume of the pump in m^3 .
- 15 6. The method according to one of the precedent claims, wherein the load estimation modul determines the estimated load using $F/A = (T \cdot \omega / \eta V_o) \cdot t$ or $F/A = (V \cdot I / V_o) \cdot t$, wherein
 - F is force in N,
 - T is torque in Nm,
 - ω is motor speed in rad/s,
 - 25 - η is efficiency of the independent motor drive,
 - V_o is total volume delivered by the pump in m^3 and $V_o = \int Q \, dt$,
 - Q is working pump flow rate in m^3/s
 - V is voltage in V,
 - I is current in A,
 - 30 - A is area over which force is applied in m^2 ,
 - t is time in s.
7. The method according to one of the precedent claims, wherein the load estimation model additionally uses working hydraulic oil temperature.
- 35 8. The method according to claim 7, wherein based on the working hydraulic oil temperature a viscosity correction factor K_v is determined and based on the viscosity correction factor a corrected pump flow rate Q_c is determined according $Q_c = K_v \cdot Q_0$, wherein Q_0 is a standard pump flow rate at a defined standard temperature and wherein the corrected flow rate is used by the load estimation modul as the pump flow rate.
- 40 9. The method according to claim 8, wherein values for the viscosity correction factor K_v for different temperatures are determined using stored values, which are preferably determined in a previous step according to $K_v = \mu / \mu_0$, wherein
 - K_v is the viscosity correction factor,
 - 45 - μ is the actual viscosity in Pa·s at a certain temperature,
 - μ_0 is the reference viscosity at a standard temperature in Pa·s.
10. A computer system for operating a working machine the computer system comprising a processing circuitry configured to perform the steps of the method according to any of claims 1 to 9.
- 50 11. A computer program comprising program code means for performing the steps of the method according to any of claims 1 to 9 when said program is executed by a processor device.
12. A non-transitory computer-readable storage medium comprising instructions, which when executed by the processor device, causes the processor device to perform the method of any of claims 1 to 9.
- 55 13. A working machine with working hydraulics and an independent motor drive for powering the working hydraulics comprising a computer system according to claim 10.

- 14.** The working machine according to claim 13, wherein the working machine is a wheel loader, preferably an electric compact wheel loader.

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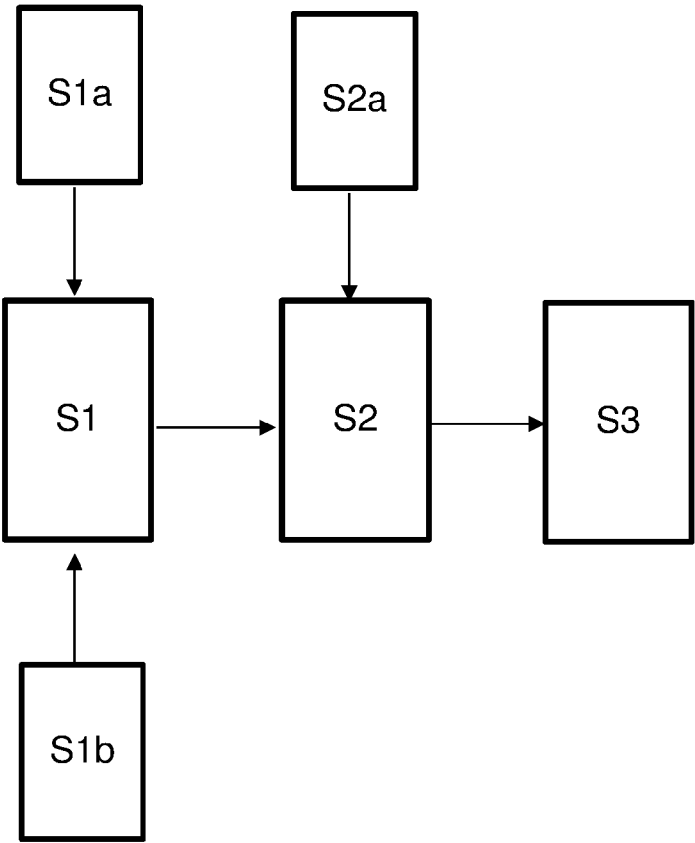


Fig. 1

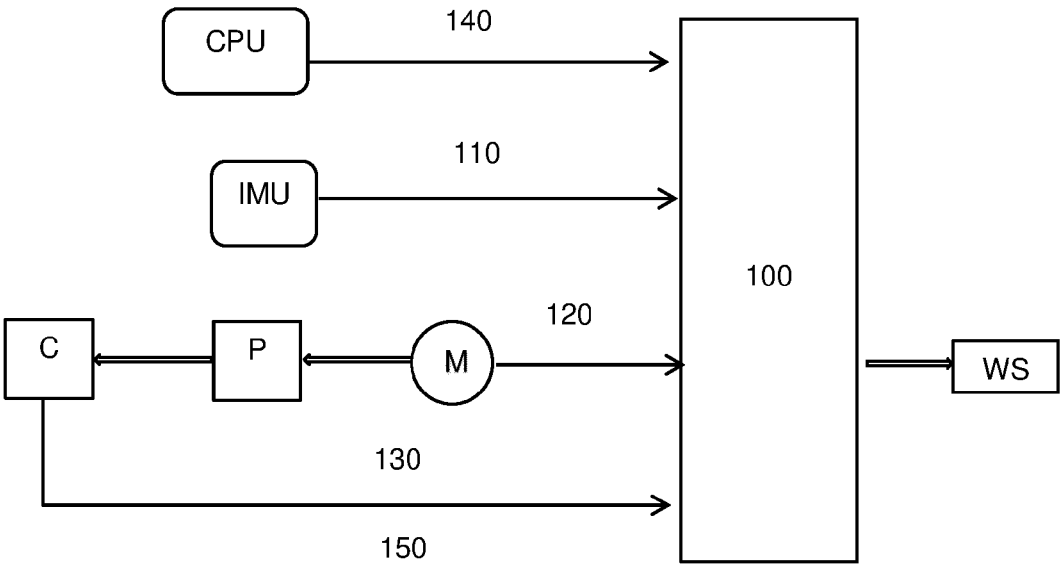


Fig. 2



EUROPEAN SEARCH REPORT

Application Number

EP 24 15 1598

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2023/098498 A1 (ANDREUCCETTI CHRISTOPHER ALAN [US] ET AL) 30 March 2023 (2023-03-30) * figures 1-3 *	1-14	INV. E02F9/20 E02F9/22 E02F9/26
A	EP 3 859 089 A1 (KOMATSU MFG CO LTD [JP]) 4 August 2021 (2021-08-04) * paragraph [0063] - paragraph [0065]; figures 1-5 *	1-14	
A	US 2014/174068 A1 (MORI KAZUSHIGE [JP] ET AL) 26 June 2014 (2014-06-26) * paragraph [0034]; figure 1 *	1-14	
			TECHNICAL FIELDS SEARCHED (IPC)
			E02F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		26 June 2024	Rocabruna Vilardell
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 15 1598

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-06-2024

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2023098498 A1	30-03-2023	BR 112022016839 A2	11-10-2022
		EP 4111002 A1	04-01-2023
		US 2023098498 A1	30-03-2023
		WO 2021173742 A1	02-09-2021

EP 3859089 A1	04-08-2021	CN 113056592 A	29-06-2021
		EP 3859089 A1	04-08-2021
		JP 7347925 B2	20-09-2023
		JP 7426524 B2	01-02-2024
		JP 2020085055 A	04-06-2020
		JP 2023121768 A	31-08-2023
		US 2021372089 A1	02-12-2021
		WO 2020105461 A1	28-05-2020

US 2014174068 A1	26-06-2014	CN 103765019 A	30-04-2014
		EP 2752586 A1	09-07-2014
		JP 5860053 B2	16-02-2016
		JP WO2013031768 A1	23-03-2015
		KR 20140063622 A	27-05-2014
		US 2014174068 A1	26-06-2014
		WO 2013031768 A1	07-03-2013

EPO FORM P0459

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