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(71) Applicant: **Palfinger AG**
5101 Bergheim bei Salzburg (AT)

(72) Inventors:
- **THUM, Daniel**
  5440 Golling an der Salzach (AT)
- **KAMATH, Hattiangadi Sanjay**
  4600 Wels (AT)

(74) Representative: **2SPL Patentanwälte PartG mbB**
Landaubogen 3
81373 München (DE)

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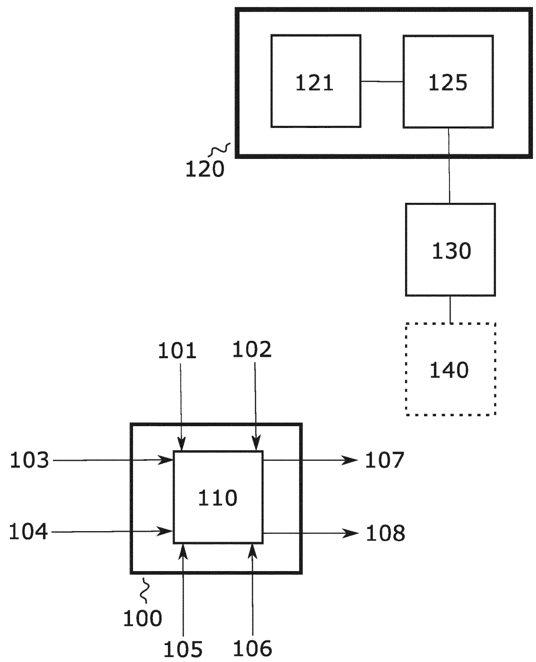
(54) **APPARATUS AND METHOD FOR DETERMINING A TARGET ROTATIONAL SPEED FOR A ROTARY DRIVE DRIVING A DISPLACEMENT PUMP OF A HYDRAULIC SYSTEM OF A LIFTING EQUIPMENT**

(57) Provided is an apparatus for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment. The apparatus includes processing circuitry configured to receive first input data indicating a current or planned future activation of the rotary drive. The processing circuitry is further configured to receive second input data indicating a measured temperature of hydraulic fluid in the hydraulic system. In addition, the processing circuitry is configured to receive third input data indicating a target temperature for the hydraulic fluid. The processing circuitry is configured to determine, in response to receiving the first input data, the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Additionally, the processing circuitry is configured to output control data indicating the determined target rotational speed.

FIG. 1



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Description

Field

[0001] The present disclosure relates to controlling rotary drives driving displacement pumps of lifting equipment. In particular, examples of the present disclosure relate to an apparatus and a method for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment, and a vehicle comprising the apparatus.

Background

[0002] Cranes, in particular loader cranes play a pivotal role in various industries, providing efficient lifting and handling capabilities. Various functions of a crane such as lifting, lowering, extending, retracting, rotating, and stabilizing use hydraulic power provided by a displacement pump of the crane. The displacement pump pumps hydraulic oil to provide the required hydraulic power.

[0003] The displacement pump of a crane is conventionally driven by a Power Take-Off (PTO) of a vehicle carrying the crane. When a crane operator engages the PTO, the PTO runs at zero Revolutions Per Minute (RPM) until the crane operator starts operation of the crane. Particularly in winter or when working in parts of the world with low ambient temperatures, the hydraulic oil may have a very low temperature. The crane operator has to wait until the hydraulic oil has heated up to the required operating temperature before he can put the crane into operation. The same problem arises with other types of lifting equipment equipped with a hydraulic system, such as forklifts or lifting platforms.

[0004] Hence, there may be a demand for improved temperature management of the hydraulic system of lifting equipment.

Summary

[0005] This demand is met by an apparatus and a method for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment, a vehicle, a non-transitory machine-readable medium and a program in accordance with the independent claims. Advantageous embodiments are defined by the dependent claims.

[0006] According to a first aspect, the present disclosure provides an apparatus for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment. The apparatus comprises processing circuitry configured to receive first input data indicating a current or planned future activation of the rotary drive. The processing circuitry is further configured to receive second input data indicating a measured temperature of hydraulic fluid in the hydraulic system. In addition, the processing circuitry is configured to receive third input data indicating a target temperature for the hydraulic fluid. The processing circuitry is configured to determine, in response to receiving the first input data, the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Additionally, the processing circuitry is configured to output control data indicating the determined target rotational speed.

[0007] According to a second aspect, the present disclosure provides a vehicle having mounted thereon or being a lifting equipment. The vehicle comprises the apparatus according to the first aspect. Control circuitry on the vehicle is configured to control the rotary drive based on the control data. The hydraulic system comprises at least one of one or more hydraulic cylinders and one or more slewing drives coupled to the displacement pump and drivable by the hydraulic fluid.

[0008] According to a third aspect, the present disclosure provides a method for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment. The method comprises receiving first input data indicating an activation or a planned future activation of the rotary drive. Further, the method comprises receiving second input data indicating a measured temperature of hydraulic fluid in the hydraulic system. In addition, the method comprises receiving third input data indicating a target temperature for the hydraulic fluid. The method comprises determining, in response to receiving the first input data, the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Additionally, the method comprises outputting control data indicating the determined target rotational speed.

[0009] According to a fourth aspect, the present disclosure provides a non-transitory machine-readable medium having stored thereon a program having a program code for performing the method according to the third aspect, when the program is executed on a processor or a programmable hardware.

[0010] According to a fifth aspect, the present disclosure provides a program having a program code for performing the method according to the third aspect, when the program is executed on a processor or a programmable hardware.

[0011] The flow of the hydraulic fluid in the hydraulic system of the lifting equipment is caused by the rotary drive driving the displacement pump of the hydraulic system. The temperature of the hydraulic fluid depends on the flow of the hydraulic fluid within the hydraulic system. By determining the target rotational speed for the rotary drive based on the measured temperature and the target temperature, the hydraulic fluid may be brought to or maintained in a desired temperature range. For example, if the measured temperature is below the target temperature, the hydraulic fluid may be heated to the target temperature by setting the target rotational speed for the rotary drive accordingly. Similarly, overheating of the hydraulic fluid may be avoided by determining the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Accordingly, improved temperature management of the lifting equipment's hydraulic system may be achieved. Proper temperature management may reduce the strain on the hydraulic system components, leading to less frequent maintenance, longer equipment life and, hence, improved sustainability.

Brief description of the Figures

[0012] Some examples of apparatuses and/or methods will be described in the following by way of example only, and with reference to the accompanying figures, in which

Fig. 1 illustrates an example of an apparatus for determining a target rotational speed for a rotary drive;

Fig. 2 illustrates an exemplary process flow;

Fig. 3 illustrates an example of a vehicle; and

Fig. 4 illustrates a flowchart of an example of a method for determining a target rotational speed for a rotary drive.

Detailed Description

[0013] Some examples are now described in more detail with reference to the enclosed figures. However, other possible examples are not limited to the features of these embodiments described in detail. Other examples may include modifications of the features as well as equivalents and alternatives to the features. Furthermore, the terminology used herein to describe certain examples should not be restrictive of further possible examples.

[0014] Throughout the description of the figures same or similar reference numerals refer to same or similar elements and/or features, which may be identical or implemented in a modified form while providing the same or a similar function. The thickness of lines, layers and/or areas in the figures may also be exaggerated for clarification.

[0015] When two elements A and B are combined using an "or", this is to be understood as disclosing all possible combinations, i.e. only A, only B as well as A and B, unless expressly defined otherwise in the individual case. As an alternative wording for the same combinations, "at least one of A and B" or "A and/or B" may be used. This applies equivalently to combinations of more than two elements.

[0016] If a singular form, such as "a", "an" and "the" is used and the use of only a single element is not defined as mandatory either explicitly or implicitly, further examples may also use several elements to implement the same function. If a function is described below as implemented using multiple elements, further examples may implement the same function using a single element or a single processing entity. It is further understood that the terms "include", "including", "comprise" and/or "comprising", when used, describe the presence of the specified features, integers, steps, operations, processes, elements, components and/or a group thereof, but do not exclude the presence or addition of one or more other features, integers, steps, operations, processes, elements, components and/or a group thereof.

[0017] **Fig. 1** schematically illustrates an apparatus 100 for determining a target rotational speed for a rotary drive (rotary actuator, rotary motion drive) 130 driving a displacement pump 125 of a hydraulic system of a lifting equipment 120.

[0018] The lifting equipment 120 is any machinery (device) for lifting loads (e.g., goods and/or people) using hydraulic power. For example, the lifting equipment may be a crane such as a knuckle boom or loader crane for loading and unloading goods (loads). Alternatively, the lifting equipment may, e.g., be the crane section of a mobile crane (with a vehicle being a mobile platform having mounted thereon the crane section) or the entire mobile crane. In other examples, the lifting equipment may, e.g., be a forklift comprising a pronged device in the front, called forks, which can be inserted under loads to lift and carry them. In still other examples, the lifting equipment may, e.g., be a lifting platform (elevating platform of lift table) comprising a platform supported by a mechanical structure in a liftable manner to a base of the lifting platform.

[0019] The rotary drive 130 is configured to produce (provide) controlled rotational movement. The target rotational speed denotes the desired or intended speed at which the rotary drive 130 should rotate. In other words, the target rotational speed refers to the desired or intended speed of the rotational movement to be provided by the rotary drive 130.

[0020] As schematically indicated in Fig. 1, the displacement pump 125 of the lifting equipment 120 is driven by the rotary drive 130 to provide hydraulic power. For example, the hydraulic power may be provided by means of a flow of hydraulic fluid caused (generated) by the displacement pump 125 when driven by the rotary drive 130. In general, any type of hydraulic fluid suitable for transmitting power efficiently may be used. For example, the hydraulic fluid may be a mineral oil-based hydraulic fluid or a synthetic hydraulic fluid. The hydraulic power provided by the displacement pump 125 is used by one or more consumers of the lifting equipment 120 (not illustrated in Fig. 1). The one or more consumers of the lifting equipment 120 are hydraulically coupled to the displacement pump 125. The displacement pump 125 and the one or more consumers of the crane 120 form the hydraulic system of the lifting equipment 120.

[0021] For example, the one or more consumers may be one or more hydraulic cylinders and/or one or more slewing drives of the lifting equipment 120 for providing various functions of the lifting equipment 120 such as lifting, lowering, extending, tilting, retracting, rotating, and stabilizing. For reasons of simplicity, various elements of the lifting equipment 120 such as its one or more hydraulic cylinders, one or more slewing drives, equipment base (e.g., the crane base of a crane or the base of a lifting platform), lifting devices (e.g., a boom or crane arm of a crane, the forks of a forklift, the platform of a lifting platform) or outriggers (e.g., crane legs) are not illustrated in Fig. 1.

[0022] The rotary drive 130 may be part of the lifting equipment 120. In other examples, the rotary drive 130 may be external to the lifting equipment 120 (e.g., external to a crane such as a loader crane). In other words, the rotary drive 130 is not part of the lifting equipment 120 in some examples. The rotary drive 130 may be any device or system capable of converting energy into mechanical rotation (rotational movement) in a controlled manner. For example, the rotary drive 130 may be an electric rotary drive comprising one or more electric motors for generating the rotational movement. According to examples of the present disclosure, the rotary drive 130 may be an electric rotary drive on a vehicle having mounted thereon (holding, carrying) lifting equipment 120 or being the lifting equipment 120. Electric rotary drives are also denoted as electric Power Take-Offs (ePTOs). In alternative examples, the rotary drive 130 may be a Power Take-Off (PTO) driven by a drive system 140 (e.g., a combustion engine and optionally a gearbox). According to examples of the present disclosure, the rotary drive 130 may be a PTO of a vehicle having mounted thereon or being the lifting equipment 120. The vehicle may be a land vehicle (e.g., wheeled, tracked or railed) or a watercraft (e.g., a ship, a boat or a barge). For example, the lifting equipment 120 may be mounted to a vehicle such as a truck. For example, the lifting equipment 120 may be a crane (e.g., a knuckle boom or loader crane) mounted to a vehicle such as a truck for loading and unloading goods onto and from the vehicle. The rotary drive 130, in particular when implemented as electric rotary drive, may be detachably attached to the vehicle. In other examples, the rotary drive 130 may be fixedly attached to the vehicle. For reasons of clarity, the vehicle is not shown in Fig. 1.

[0023] The apparatus 100 may be part of the lifting equipment 120 (e.g., be part of a crane). According to examples, equipment control circuitry (equipment controller) 121 for controlling operation of the lifting equipment 120 may comprise the apparatus 100. The equipment control circuitry 121 may, e.g., be coupled to the displacement pump 125 and control operation of the displacement pump 125 and optionally further elements of the lifting equipment 120. In other examples, the apparatus 100 and the equipment control circuitry 121 may be separate elements of the lifting equipment 120. In alternative examples, the apparatus 100 may be external to the lifting equipment 120, i.e., not be part of the lifting equipment 120. For example, a computing cloud communicatively coupled to the lifting equipment 120 (e.g., via a wireless connection) may comprise or be the apparatus 100. In still other examples, the vehicle having mounted thereon the lifting equipment 120 may comprise the apparatus 100. In case the lifting equipment 120 is a crane, the equipment control circuitry 121 may be crane control circuitry (a crane controller) for controlling operation of the crane.

[0024] The apparatus 100 comprises processing circuitry 110. For example, the processing circuitry 110 may be a single dedicated processor, a single shared processor, or a plurality of individual processors, some of which or all of which may be shared, a digital signal processor (DSP) hardware, an application specific integrated circuit (ASIC), a system-on-a-chip (SOC), a neuromorphic processor or a field programmable gate array (FPGA). The processing circuitry 110 may optionally be coupled to, e.g., memory such as read only memory (ROM) for storing software, random access memory (RAM) and/or non-volatile memory. For example, the apparatus 100 may comprise memory configured to store instructions, which when executed by the processing circuitry 110, cause the processing circuitry 110 to perform the steps and methods described herein.

[0025] The processing circuitry 110 is configured to receive first input data 101. The first input data 101 indicate (are encoded with information about) a current or planned future activation of the rotary drive 130. In other words, the first input data 101 convey information about whether the rotary drive 130 is currently active (i.e., it is running or engaged at this moment) or if there is an intention or schedule for it to be activated in the future (i.e., it is planned to start running at a later time). If the first input data 101 indicate a planned future activation of the rotary drive 130, the first input data 101 may, e.g., indicate one or more of a scheduled (planed) time for activation, or one or more conditional triggers that will cause the rotary drive 130 to start. The first input data 101 may be received from various sources. For example, if the first input data 101 indicate a current activation of the rotary drive 130, the processing circuitry 110 may be configured to receive the first input data 101 from circuitry (e.g., control circuitry) of a vehicle having mounted thereon or being the lifting equipment 120. In particular, the first input data 101 may be received from control circuitry of/for the rotary drive 130. On the other hand, if the first input data 101 indicate a planned future activation of the rotary drive 130, the processing circuitry 110 may be configured to receive the first input data 101 from a computing cloud (not illustrated in Fig. 1) communicatively coupled to the apparatus 100 (e.g., via a wireless connection). The computing cloud may, e.g., manage the activity of the lifting device and, e.g., schedule jobs for the lifting equipment 120. For example, if a job is available, the computing cloud may send the first input data 101 to the apparatus 100. However, the present disclosure is not limited thereto. In other examples, the first input data 101 may be received from another entity (element, circuitry).

[0026] Further, the processing circuitry 110 is configured to receive second input data 102 indicating a measured temperature of the hydraulic fluid in the hydraulic system. The second input data 102 reflect the current temperature of the hydraulic fluid. For example, the temperature of the hydraulic fluid in the hydraulic system may be measured via one or more temperature sensors arranged within the hydraulic system. The processing circuitry 110 may be configured to directly receive the second input data 102 from the one or more temperature sensors or from an intermediate element such as (control) circuitry or a buffer memory of the lifting equipment 120. The second input data 102 may be time-series data indicating a plurality of measurement values for the temperature of the hydraulic fluid over time. The second input data 102 may be received continuously by the processing circuitry 110.

[0027] The processing circuitry 110 is additionally configured to receive third input data 103 indicating a target temperature for the hydraulic fluid. The target temperature denotes the desired or intended temperature for the hydraulic fluid within the hydraulic system. The third input data 103 may be received from various sources. For example, the processing circuitry 110 may be configured to receive the third input data 103 from (control) circuitry or a memory of the lifting equipment 120. In other examples, the third input data 103 may be received from another entity of the lifting equipment 120 such as a Human-Machine Interface (HMI) of the lifting equipment 120. In still other examples, the third input data 103 may be received from a remote control (not illustrated in Fig. 1) of the lifting equipment 120. The remote control is a device for an operator (user) of the lifting equipment 120 for controlling the lifting equipment 120 from a distance. However, the present disclosure is not limited thereto. In other examples, the third input data 103 may be received from a user device or mobile device (e.g., a mobile phone, a laptop-computer or a tablet-computer) of the operator of the lifting equipment 120 or a remote server. According to examples, a manufacturer of the lifting equipment 120 may, e.g., (fixedly) set the target temperature for the hydraulic fluid. In other examples, the operator of the lifting equipment 120 may set (adjust) the target temperature (e.g., via a corresponding user input at the remote control or the mobile device). The target temperature may be selected (set) to ensure proper viscosity of the hydraulic fluid. The lower the temperature of the hydraulic fluid, the more viscous (thick) is the hydraulic fluid. If the hydraulic fluid is too viscous (thick), it can cause excessive resistance, leading to inefficient operation and increased wear on components. On the other hand, if the fluid is too thin (low viscosity), it may not provide adequate lubrication, leading to increased friction and potential damage to the system. For example, the target temperature may be 0 °C or more, 5 °C or more, 10 °C or more, 15 °C or more, or 20 °C or more. Similarly, the target temperature may be 100 °C or less, 90 °C or less, 80 °C or less, 70 °C or less, 60 °C or less, or 50 °C or less.

[0028] In response to receiving the first input data 101, the processing circuitry 110 is configured to determine the target rotational speed for the rotary drive 130 based on the measured temperature and the target temperature. In other words, if the first input data 101 indicate a current or planned future activation of the rotary drive 130, the processing circuitry 110 determines the target rotational speed using the measured temperature indicated by the second input data 102 and the target temperature indicated by the third input data 103 as input for the determination. The target rotational speed may be constant over time or may vary over time. The processing circuitry 110 may be configured to determine the target rotational speed using a predefined computational model. The computational model is a mathematical representation (e.g., a set of mathematical equations) for determining the target rotational speed for the rotary drive 130 taking into account the measured temperature indicated by the second input data 102, the target temperature indicated by the third input data 103 and optionally further inputs (see examples below). The computational model may use various signal and/or data processing operations such as signal/data addition, subtraction, multiplication, division, integration, derivation, filtering (e.g., discrete, continuous or both), delaying, etc. to determine the target rotational speed based on the various inputs to the processing circuitry 110.

[0029] The processing circuitry 110 is configured to output control data 107 indicating the determined target rotational speed. The control data 107 are for controlling the rotational speed of the rotary drive 130. The control data 107 may be output by the processing circuitry 110 to various entities - depending on the implementation of the rotary drive 130. For example, the processing circuitry 110 may be configured to output the control data 107 to the rotary drive 130 such that control circuitry of the rotary drive 130 may control the rotary drive 130 to adjust its rotational speed to the determined target rotational speed. In other examples, the processing circuitry 110 may be configured to output the control data 107 to control circuitry for the rotary drive 130 external to the rotary drive 130 such that the external control circuitry may control the rotary drive 130 to adjust its rotational speed to the determined target rotational speed. For example, if the rotary drive is an electric rotary drive on a vehicle having mounted thereon or being the lifting equipment 120, the processing circuitry 110 may be configured to output the control data 107 to the electric rotary drive such that control circuitry of the electric rotary drive may control the electric rotary drive to adjust its rotational speed to the determined target rotational speed. In case the rotary drive 130 is driven by the drive system 140, the processing circuitry 110 may be configured to output the control data 107 to the drive system 140 or control circuitry for the drive system 140 external to the drive system 140 such that the drive system 140 is controlled to adjust the driving of the rotary drive 130 such that the rotational speed of the rotary drive 130 is adjusted to the determined target rotational speed. For example, if the rotary drive 130 is a PTO of a vehicle having mounted thereon or being the lifting equipment 120, the processing circuitry 110 may be configured to output the control data 107 to the vehicle such that vehicle control circuitry of the vehicle may control the drive system 140 of the vehicle (e.g., a combustion engine of the vehicle) based on the control data 107.

[0030] The flow of the hydraulic fluid in the hydraulic system of the lifting equipment 120 is caused by the rotary drive 130 driving the displacement pump 125. The temperature of the hydraulic fluid depends on the flow of the hydraulic fluid within the hydraulic system. By determining the target rotational speed for the rotary drive 130 based on the measured temperature and the target temperature, the hydraulic fluid may be brought to or maintained in a desired temperature range. For example, if the measured temperature is below the target temperature, the hydraulic fluid may be heated to the target temperature by setting the target rotational speed for the rotary drive 130 accordingly. Similarly, overheating of the hydraulic fluid may be avoided by determining the target rotational speed for the rotary drive 130 based on the measured temperature and the target temperature. Accordingly, improved temperature management of the lifting equipment 120's hydraulic system may be achieved. Proper temperature management may reduce the strain on the hydraulic system components, leading to less frequent maintenance, longer equipment life and, hence, improved sustainability.

[0031] The second input data 102 as well as other input data to the processing circuitry 110 may be real-time data (i.e., data that is delivered/received immediately after collection/generation without significant delay). This may ensure that the target rotational speed can be dynamically adjusted. This real-time feedback loop helps in maintaining optimal performance and safety.

[0032] As indicated above, the hydraulic fluid may be heated to the target temperature by setting the target rotational speed for the rotary drive 130 accordingly. For example, if the measured temperature is less than the target temperature, the processing circuitry 110 may be configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature. Accordingly, proper viscosity of the hydraulic fluid may be ensured. In the following, various examples for determining the target rotational speed to cause heating of the hydraulic fluid will be described in greater detail. However, it is to be noted that the present disclosure is not limited thereto. Other approaches for determining the target rotational speed may be used according to examples of the present disclosure.

[0033] If the first input data 101 indicate a planned future activation of the rotary drive 130, the processing circuitry 110 may, e.g., be configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature by the time of the planned future activation of the rotary drive 130. In other words, if the first input data 101 indicate that the rotary drive 130 is (e.g., not currently active but is) scheduled to be activated at a future time, the processing circuitry 130 may be configured to determine the target rotational speed needed to heat the hydraulic fluid to the target temperature by the time the rotary drive 130 is scheduled to start. Further, the processing circuitry 130 may be configured to determine a time window during which the rotary drive 130 is to rotate at the target rotational speed such that the hydraulic fluid is heated to the target temperature by the time of the planned future activation of the rotary drive 130. The control data 107 may indicate the determined target rotational speed and the time window. The above processing may ensure that the hydraulic fluid reaches the target temperature (e.g., a minimum or optimal operating temperature) precisely when the rotary drive 130 is activated, promoting efficient and effective system operation from the moment of activation. This may allow to reduce energy emissions, reduce effects on the environment and, hence, improve sustainability.

[0034] If the first input data 101 indicate a current activation of the rotary drive 130, the processing circuitry 110 may, e.g., be configured to determine the target rotational speed to cause instantaneous (immediate) heating of the hydraulic fluid to the target temperature. In other words, if the first input data 101 indicate that the rotary drive 130 is currently active, the processing circuitry 130 may be configured to determine the target rotational speed needed to instantly (immediately) heat the hydraulic fluid to the target temperature (i.e., heat the hydraulic fluid right away without any lag). The above processing may quickly bring the hydraulic fluid to the desired temperature, ensuring optimal performance and preventing issues related to suboptimal fluid temperature during operation.

[0035] According to examples of the present disclosure, the processing circuitry 110 may be further configured to receive fourth input data 104 indicating a demanded rotational speed of the rotary drive 130 for operation of the lifting equipment. The demanded rotational speed denotes the specific speed at which the rotary drive 130 should operate to meet the performance requirements of the lifting equipment 120. The demanded rotational speed ensures that the hydraulic fluid is supplied (pumped) by the displacement pump 125 at a target flow rate ensuring sufficient hydraulic power for the intended operation of the lifting equipment 120. The fourth input data 104 may, e.g., be received from the equipment control circuitry 121. The equipment control circuitry 121 controls the operation of the lifting equipment 120 and is, hence, aware of or able to calculate the required flow rate of hydraulic fluid for the (e.g., intended) operation of the lifting equipment 120. Accordingly, the equipment control circuitry 121 is aware of or able to calculate the required rotational speed of the rotary drive 130 for the (e.g., intended) operation of the lifting equipment 120. However, the present disclosure is not limited thereto. In other examples, the fourth input data 104 may be received from another entity (element, circuitry) of the lifting equipment 120.

[0036] In these examples, the processing circuitry 110 may be configured to determine the target rotational speed further based on the demanded rotational speed. The lifting equipment 120 has different hydraulic power demands depending on its operation. This is reflected by additionally taking into account the fourth input data 104 for the determination the target rotational speed. The demanded rotational speed may be considered in various ways. In the following a few examples will be given. However, it is to be noted that the present disclosure is not limited to these examples.

[0037] For example, if the measured temperature is less than the target temperature, the processing circuitry 110 may be configured to determine the target rotational speed to be higher than the demanded rotational speed to cause heating of the hydraulic fluid to the target temperature. This increased rotational speed helps generate additional heat, raising the temperature of the hydraulic fluid to the target level. Running the rotary drive 130 at a higher rotational speed than is necessary for the actual operation of the lifting equipment 120 generates more friction and, hence, heat in the hydraulic system, which in turn helps to raise the temperature of the hydraulic fluid. The offset between the demanded rotational speed and the target rotational speed may be determined in various ways. In the following two examples will be given.

[0038] According to a first example, the processing circuitry 110 may be further configured to receive fifth input data 105 indicating a predefined rotational speed offset and be configured to increase the demanded rotational speed by the predefined rotational speed offset to determine the target rotational speed. The predefined rotational speed offset refers to a set value or adjustment factor that is used to increase the determined target rotational speed for the rotary drive 130 by a certain amount. For example, if the target rotational speed for the rotary drive 130 is, based on the measured temperature indicated by the second input data 102, the target temperature indicated by the third input data 103, the demanded rotational speed indicated by the fourth input data 104 and optionally further inputs, determined to be X revolutions per unit time and the predefined rotational speed offset is Y revolutions per unit time, the resulting target rotational speed is $Z = X + Y$ revolutions per time unit. In other examples, if an adjustment factor $A \geq 1$ is used instead of the set value Y, the resulting target rotational speed is $Z = X \cdot A$ revolutions per time unit. The predefined rotational speed offset allows to ensure that the target rotational speed accounts for the additional heat needed to raise the hydraulic fluid temperature to the desired level. Accordingly, too low rotational speeds of the rotary drive 130 resulting in insufficient heating of the hydraulic fluid may be avoided. The fifth input data 105 may, e.g., be received from the equipment control circuitry 121, the remote control or any other element or circuitry of the lifting equipment 120. For example, the predefined rotational speed offset may be determined (set) by a manufacturer of the lifting equipment. In other examples, the predefined rotational speed offset may be determined (set) by a user input at, e.g., the remote control.

[0039] According to an alternative second example, the processing circuitry 110 may be configured to dynamically determine a rotational speed offset based on the difference between the measured temperature and the target temperature, and be configured to increase the demanded rotational speed by the rotational speed offset to determine the target rotational speed. In other words, the processing circuitry 110 may be configured to monitor the current temperature of the hydraulic fluid and compare it to the desired target temperature. The difference between these two values indicates how much heating is needed. The rotational speed offset is not a fixed value but is calculated dynamically based on the temperature difference. The processing circuitry 110 is configured to determine the rotational speed offset substantially in real-time based on the temperature difference. For example, the processing circuitry 110 may be configured to determine the rotational speed offset at a rate of 0.1 Hz or more, 0.5 Hz or more, 1 Hz or more, 10 Hz or more, 50 Hz or more, or 100 Hz or more. A larger difference between the measured temperature and the target temperature would result in a larger rotational speed offset, meaning a greater increase in rotational speed to generate more heat. Conversely, a smaller difference would result in a smaller offset. The dynamic determination allows for precise control over the heating process, ensuring the hydraulic fluid reaches the target temperature accurately. Adjusting the target rotational speed based on real-time data ensures that the hydraulic system only generates as much heat as needed, improving energy efficiency. The dynamic determination allows to adapt to various operating conditions and temperature discrepancies, providing flexibility and robustness.

[0040] The processing circuitry 110 may be configured to determine the target rotational speed to be higher than the demanded rotational speed until the measured temperature reaches the target temperature. In other words, the processing circuitry 110 may be configured to set the target rotational speed of the rotary drive 130 to be higher than the demanded rotational speed (e.g., according to one of the above examples) and continuously maintain the elevated speed until the hydraulic fluid reaches the target temperature. The target rotational speed is set higher than the demanded rotational speed to generate additional heat through the rotary drive 130's operation. This additional heat helps raise the temperature of the hydraulic fluid to the target level.

[0041] On the other hand, the processing circuitry 110 may be configured to determine the target rotational speed to be the demanded rotational speed once the measured temperature has reached the target temperature. Once the desired temperature is achieved, the hydraulic system no longer needs the elevated speed to generate additional heat and the target rotational speed can revert to the demanded rotational speed for the operation of the lifting equipment 120. In other words, once the hydraulic fluid reaches the target temperature, the processing circuitry 110 may be configured to reduce the target rotational speed to the demanded rotational speed.

[0042] If the temperature of the hydraulic fluid is at or above the target temperature, there is no need for additional heating. Accordingly, if the measured temperature is equal to or higher than the target temperature, the processing circuitry 110 may be configured to determine the target rotational speed to be the demanded rotational speed, which is the speed demanded for regular operations of the lifting equipment without additional heat generation.

[0043] According to examples of the present disclosure, hysteresis may be used for the determination of the target rotational speed. For example, the processing circuitry 110 may be further configured to receive sixth input data 106 indicating a hysteresis range for the target temperature. Accordingly, the processing circuitry 110 may be configured to determine the target rotational speed further based on the hysteresis range. The hysteresis range is a tolerance band around the target temperature that helps prevent frequent, small adjustments to the target rotational speed, which can lead to inefficiency and wear. The hysteresis range defines a temperature band within which the processing circuitry 110 does not need to adjust the target rotational speed. For example, if the target temperature is 10 °C and the hysteresis range is ±2 °C, the system will maintain the current settings for the target rotational speed as long as the measured temperature is between 8°C and 12°C. The hysteresis based determination of the target rotational speed may avoid rapid switching between zero target rotational speed and non-zero target rotational speed (i.e., rapidly switching on and off the rotary drive 130). For example, if the computational model for determining the target rotational speed uses a fixed step solver, sudden behavioral changes which can lead to higher zero crossings and slower run time may be avoided due to the consideration of the hysteresis.

[0044] The status of the heating of the hydraulic fluid may further be indicated at the remote control of the lifting equipment 120 or the mobile/user device of the operator of the lifting equipment 120. According to examples of the present disclosure, the processing circuitry 110 may be further configured to cause output of status data 108 to at least one of the remote control of the lifting equipment 120 and the mobile/user device of the operator of the lifting equipment 120. For example, the processing circuitry 110 may be configured to control interface circuitry of the apparatus 100 or the lifting equipment 120 to transmit the status data 108 to the at least one of the remote control of the lifting equipment 120 and the mobile/user device of the operator of the lifting equipment 120 (e.g., via a wireless or a wired transmission).

[0045] The status data indicate information related to at least one of the temperature of the hydraulic fluid and the determined target rotational speed. For example, the information related to the temperature of the hydraulic fluid may be the current (measured) temperature of the hydraulic fluid, the target temperature for the hydraulic fluid, a trend of the measured temperature of the hydraulic fluid (i.e., the change of the measured temperature of the hydraulic fluid over time), the time by which the target temperature needs to be achieved, an indicator indicating whether the hydraulic fluid is currently heated or heating of the hydraulic fluid is planned (e.g., further indicating a planned time window for heating the hydraulic fluid), etc. The information related to the determined target rotational speed may, e.g., be the current target rotational speed, a trend of the target rotational speed (i.e., the change of the determined target rotational speed over time), the time by which the target temperature needs to be achieved, an indicator indicating whether the target rotational speed is currently higher than the demanded rotation speed to cause heating of the hydraulic fluid or whether an increase of the demanded rotation speed is planned (e.g., further indicating a planned time window for heating the hydraulic fluid by increasing the demanded rotation speed), the used rotational speed offset, etc.

[0046] Accordingly, the remote control or the mobile/user device of the operator may indicate the information related to the at least one of the temperature of the hydraulic fluid and the determined target rotational speed to the operator. For example, the remote control or the mobile/user device of the operator may control light emission by one or more status lights of the remote control based on the status data 108 to indicate the information related to the at least one of the temperature of the hydraulic fluid and the determined target rotational speed to the operator. Similarly, the remote control or the mobile/user device of the operator may control its display to output graphical elements and/or textual elements as part of a graphical user interface based on the status data 108 to indicate the information related to the at least one of the temperature of the hydraulic fluid and the determined target rotational speed to the operator. Accordingly, the operator may be informed by the remote control or the mobile/user device about the information related to the at least one of the temperature of the hydraulic fluid and the determined target rotational speed to the operator.

[0047] **Fig. 2** illustrates an exemplary process flow 200 summarizing the above described aspects for determining the target rotational speed for the rotary drive. In the example of Fig. 2, it is assumed that the lifting equipment is a crane, that the rotary drive is a PTO and that the hydraulic fluid is hydraulic oil.

[0048] At 202, the operator of the crane engages, i.e., activates, the PTO. A temperature sensor measures the temperature of the hydraulic oil and detects at 204 a low temperature while the operator prepares himself at 206 for operation of the crane (e.g., puts on safety gear and grabs a remote control for the crane). For example, during winter, the hydraulic oil may be at a very low temperature after the operator engages the PTO.

[0049] As described above, first input data indicating the activation of the PTO at 202, second input data indicating the measured temperature of the hydraulic oil (in particular, the low temperature measured at 204), third input data indicating the target temperature for the oil and fourth input data indicating the demanded rotational speed for operation of the crane are sent to the processing circuitry. The processing circuitry determines the target rotational speed to cause heating of the hydraulic oil as indicated at 208. Even if there's no demand from the crane (i.e., the demanded rotational speed is zero), the determined target rotational speed is driving the displacement pump to heat up the oil.

[0050] If the temperature of the hydraulic oil is good, i.e., high enough, as indicated at 210, the temperature of the hydraulic oil is prepared for operation of the crane as indicated at 212. Accordingly, the target rotational speed is set to zero until the operator is using the crane as indicated at 214 (the demanded rotational speed is zero until the operator is using the crane). If the operator uses the crane as indicated at 216, the hydraulic oil is heated sufficiently and the crane is fully operational. For example, the hydraulic oil is heated sufficiently while the operator prepares himself for the operation of the crane. Once the operator starts using the crane, the temperature of the oil is again checked. If the temperature of the hydraulic oil is again below a target value, the processing circuitry determines the target rotational speed to be higher than the demanded rotational speed for the operation of the crane (which is non-zero in this case) until the temperature of the hydraulic oil is good as indicated at 218. Once the oil temperature is good, all crane modes are now working as desired and the processing circuitry determines the target rotational speed to be the demanded rotational speed for the operation of the crane as indicated at 220.

[0051] On the other hand, if the operator starts using the crane before the temperature of the hydraulic oil is high enough (illustrated by the direct connection of boxes 208 and 216 in Fig. 2), the processing circuitry determines the target rotational speed to be higher than the demanded rotational speed for the operation of the crane (which is non-zero in this case) until the temperature of the hydraulic oil is good as indicated at 218. Once the temperature of the hydraulic oil is good, the processing circuitry determines the target rotational speed to be the demanded rotational speed for the operation of the crane as indicated at 220 - analogously to what is described above.

[0052] Furthermore, as indicated at 222, information related to at least one of the temperature of the hydraulic fluid and the determined target rotational speed may be signaled to the operator. For example, the information may be presented to the operator via the remote control of the crane.

[0053] **Fig. 3** further illustrates a truck as an exemplary vehicle 300 having mounted thereon (holding) a loader crane (knuckle boom crane) 320 as an exemplary lifting equipment. In the example of Fig. 3, the loader crane 320 comprises hydraulic cylinders 321, 322 and 323 for driving (moving) the crane arm 324 of the loader crane 320. The crane arm 324 is an exemplary lifting device of a lifting equipment. Additionally, the loader crane 320 comprises hydraulic cylinders 325 for driving (moving) the outriggers 326. Further illustrated in Fig. 3 is the slewing drive 328 for rotating the crane arm 324 relative to the base 327 of the loader crane 320. The hydraulic cylinders and the slewing drive(s) are hydraulically coupled to the displacement pump 125 of the loader crane 320 and form the hydraulic system of the loader crane 320. The hydraulic cylinders and the slewing drive(s) are drivable (driven) by the displacement pump 125 of the loader crane 320. The displacement pump 125 of the loader crane 320 is driven by the rotary drive 130 on the vehicle 300.

[0054] The vehicle 300 further comprises the apparatus 100 according to the present disclosure for determining a target rotational speed for the rotary drive 130. As described above, the rotary drive 130 may, e.g., be a PTO of the vehicle 300. For example, the PTO may be driven by a combustion engine and optionally a gearbox of the vehicle 300. In alternative examples, the rotary drive 130 may be an electric rotary drive (ePTO) on the vehicle 300. For reasons of simplicity, the rotary drive 130 is illustrated schematically in Fig. 3.

[0055] Control circuitry 310 on the vehicle 310 is configured to control the rotary drive 130 based on the control data 107 output by the apparatus 100. As described above, the control circuitry 310 may be manifold depending on the type of rotary drive.

[0056] Compared to conventional vehicles, the vehicle 300 may achieve improved temperature management of the loader crane 320's hydraulic system, which in turn may reduce the strain on the hydraulic system components, resulting in less frequent maintenance, longer equipment life and, hence, improved sustainability.

[0057] Fig. 3 focused on the loader crane 320 as an exemplary lifting equipment. However, as indicated above, present disclosure is not limited to the lifting equipment being the loader crane 320 mounted to the vehicle 300. In general, the lifting equipment may be any type of crane using a displacement pump to provide hydraulic power. Apart from a knuckle boom or loader crane for loading and unloading goods (loads), the lifting equipment may, e.g., be the crane section of a mobile crane (with the vehicle being the mobile platform having mounted thereon the crane section) or the entire mobile crane. It is to be noted further that the present disclosure is not limited to cranes. In other examples, the lifting equipment may, e.g., be a forklift using a displacement pump to provide hydraulic power for various applications such as raising and lowering its forks or tilting the mast of the forklift to which the forks are mounted. In still other examples, the lifting equipment may, e.g., be a lifting platform using a displacement pump to provide hydraulic power for various applications such as raising and lowering its platform.

[0058] For further highlighting the driving of displacement pumps of lifting equipment described above, **Fig. 4** illustrates a flowchart of a method 400 for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment. The method 400 comprises receiving 402 first input data indicating an activation or a planned future activation of the rotary drive. Further, the method 400 comprises receiving 404 second input data indicating a measured temperature of hydraulic fluid in the hydraulic system. In addition, the method 400 comprises receiving 406 third input data indicating a target temperature for the hydraulic fluid. The method 400 comprises determining 408, in response to receiving the first input data, the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Additionally, the method 400 comprises outputting 410 control data indicating the determined target rotational speed.

[0059] Analogously to what is described above, the method 400 may allow to bring or maintain the hydraulic fluid to/in a desired temperature range. Accordingly, improved temperature management of the lifting equipment's hydraulic system may be achieved, which in turn may reduce the strain on the hydraulic system components, resulting in less frequent maintenance, longer equipment life and, hence, improved sustainability.

[0060] More details and aspects of the method 400 are explained in connection with the proposed technique or one or more examples described above (e.g., Fig. 1 to Fig. 3). The method 400 may comprise one or more additional optional features corresponding to one or more aspects of the proposed technique or one or more examples described above.

[0061] The examples described herein may be summarized as follows:

An example (e.g., example 1) relates to an apparatus for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment. The apparatus comprises processing circuitry configured to receive first input data indicating a current or planned future activation of the rotary drive. The processing circuitry is further configured to receive second input data indicating a measured temperature of hydraulic fluid in the hydraulic system. In addition, the processing circuitry is configured to receive third input data indicating a target temperature for the hydraulic fluid. The processing circuitry is configured to determine, in response to receiving the first input data, the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Additionally, the processing circuitry is configured to output control data indicating the determined target rotational speed.

[0062] Another example (e.g., example 2) relates to a previous example (e.g., example 1) or to any other example, wherein, if the measured temperature is less than the target temperature, the processing circuitry is configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature.

[0063] Another example (e.g., example 3) relates to a previous example (e.g., example 1) or to any other example, wherein, if the first input data indicate a planned future activation of the rotary drive, the processing circuitry is configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature by the time of the planned future activation of the rotary drive, and, if the first input data indicate a current activation of the rotary drive, the processing circuitry is configured to determine the target rotational speed to cause instantaneous heating of the hydraulic fluid to the target temperature.

[0064] Another example (e.g., example 4) relates to a previous example (e.g., one of the examples 1 to 3) or to any other example, wherein the processing circuitry is further configured to receive fourth input data indicating a demanded rotational speed of the rotary drive for operation of the lifting equipment, and wherein the processing circuitry is configured to determine the target rotational speed based on the demanded rotational speed.

[0065] Another example (e.g., example 5) relates to a previous example (e.g., example 4) or to any other example, wherein, if the measured temperature is less than the target temperature, the processing circuitry is configured to determine the target rotational speed to be higher than the demanded rotational speed to cause heating of the hydraulic fluid to the target temperature.

[0066] Another example (e.g., example 6) relates to a previous example (e.g., example 5) or to any other example, wherein the processing circuitry is further configured to receive fifth input data indicating a predefined rotational speed offset, and wherein the processing circuitry is configured to increase the demanded rotational speed by the predefined rotational speed offset to determine the target rotational speed.

[0067] Another example (e.g., example 7) relates to a previous example (e.g., example 5) or to any other example, wherein the processing circuitry is further configured to dynamically determine a rotational speed offset based on the difference between the measured temperature and the target temperature, and wherein the processing circuitry is configured to increase the demanded rotational speed by the rotational speed offset to determine the target rotational speed.

[0068] Another example (e.g., example 8) relates to a previous example (e.g., one of the examples 5 to 7) or to any other example, wherein the processing circuitry is configured to determine the target rotational speed to be higher than the demanded rotational speed until the measured temperature reaches the target temperature.

[0069] Another example (e.g., example 9) relates to a previous example (e.g., one of the examples 5 to 8) or to any other example, wherein the processing circuitry is configured to determine the target rotational speed to be the demanded rotational speed once the measured temperature has reached the target temperature.

[0070] Another example (e.g., example 10) relates to a previous example (e.g., one of the examples 4 to 9) or to any other example, wherein, if the measured temperature is equal to or higher than the target temperature, the processing circuitry is configured to determine the target rotational speed to be the demanded rotational speed.

[0071] Another example (e.g., example 11) relates to a previous example (e.g., one of the examples 1 to 10) or to any other example, wherein the processing circuitry is further configured to receive sixth input data indicating a hysteresis range for the target temperature, and wherein the processing circuitry is configured to determine the target rotational speed further based on the hysteresis range.

[0072] Another example (e.g., example 12) relates to a previous example (e.g., one of the examples 1 to 11) or to any other example, wherein the processing circuitry is further configured to cause output of status data to a remote control of the lifting equipment or a user device of an operator of the lifting equipment, the status data indicating information related to at least one of the temperature of the hydraulic fluid and the determined target rotational speed.

[0073] Another example (e.g., example 13) relates to a previous example (e.g., one of the examples 1 to 12) or to any other example, wherein the first input data indicate a current activation of the rotary drive, and wherein the processing circuitry is configured to receive the first input data from circuitry of a vehicle having mounted thereon or being the lifting equipment.

[0074] Another example (e.g., example 14) relates to a previous example (e.g., one of the examples 1 to 12) or to any other example, wherein the first input data indicate a planned future activation of the rotary drive, and wherein the processing circuitry is configured to receive the first input data from a computing cloud communicatively coupled to the apparatus.

[0075] Another example (e.g., example 15) relates to a previous example (e.g., one of the examples 1 to 14) or to any other example, wherein the rotary drive is a power take-off of a vehicle, the vehicle having mounted thereon or being the lifting equipment.

[0076] Another example (e.g., example 16) relates to a previous example (e.g., one of the examples 1 to 14) or to any other example, wherein the rotary drive is an electric rotary drive on a vehicle, the vehicle having mounted thereon or being the lifting equipment.

[0077] An example (e.g., example 17) relates to vehicle having mounted thereon or being a lifting equipment. The vehicle comprises the apparatus according to a previous example (e.g., one of the examples 1 to 16) or to any other example. Control circuitry on the vehicle is configured to control the rotary drive based on the control data. The hydraulic system comprises at least one of one or more hydraulic cylinders and one or more slewing drives coupled to the displacement pump and drivable by the hydraulic fluid.

[0078] Another example (e.g., example 18) relates to a previous example (e.g., example 17) or to any other example, wherein the at least one of the one or more hydraulic cylinders and the one or more slewing drives is configured to drive at least one of a lifting device of the lifting equipment and an outrigger of the lifting equipment.

[0079] Another example (e.g., example 19) relates to a previous example (e.g., one of the examples 17 or 18) or to any other example, wherein the lifting equipment is a loader crane.

[0080] An example (e.g., example 20) relates to a method for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment. The method comprises receiving first input data indicating an activation or a planned future activation of the rotary drive. Further, the method comprises receiving second input data indicating a measured temperature of hydraulic fluid in the hydraulic system. In addition, the method comprises receiving third input data indicating a target temperature for the hydraulic fluid. The method comprises determining, in response to receiving the first input data, the target rotational speed for the rotary drive based on the measured temperature and the target temperature. Additionally, the method comprises outputting control data indicating the determined target rotational speed.

[0081] Another example (e.g., example 21) relates to a non-transitory machine-readable medium having stored thereon a program having a program code for performing the method according to a previous example (e.g., example 20) or to any other example, when the program is executed on a processor or a programmable hardware.

[0082] Another example (e.g., example 22) relates to a program having a program code for performing the method according to according to a previous example (e.g., example 20) or to any other example, when the program is executed on a processor or a programmable hardware.

[0083] The aspects and features described in relation to a particular one of the previous examples may also be combined with one or more of the further examples to replace an identical or similar feature of that further example or to additionally introduce the features into the further example.

[0084] Examples may further be or relate to a (computer) program including a program code to execute one or more of the above methods when the program is executed on a computer, processor or other programmable hardware component. Thus, steps, operations or processes of different ones of the methods described above may also be executed by programmed computers, processors or other programmable hardware components. Examples may also cover program storage devices, such as digital data storage media, which are machine-, processor- or computer-readable and encode and/or contain machine-executable, processor-executable or computer-executable programs and instructions. Program storage devices may include or be digital storage devices, magnetic storage media such as magnetic disks and magnetic tapes, hard disk drives, or optically readable digital data storage media, for example. Other examples may also include computers, processors, control units, (field) programmable logic arrays ((F)PLAs), (field) programmable gate arrays ((F)PGAs), graphics processor units (GPU), application-specific integrated circuits (ASICs), integrated circuits (ICs) or system-on-a-chip (SoCs) systems programmed to execute the steps of the methods described above.

[0085] It is further understood that the disclosure of several steps, processes, operations or functions disclosed in the description or claims shall not be construed to imply that these operations are necessarily dependent on the order described, unless explicitly stated in the individual case or necessary for technical reasons. Therefore, the previous description does not limit the execution of several steps or functions to a certain order. Furthermore, in further examples, a single step, function, process or operation may include and/or be broken up into several sub-steps, -functions, -processes or -operations.

[0086] If some aspects have been described in relation to a device or system, these aspects should also be understood as a description of the corresponding method. For example, a block, device or functional aspect of the device or system may correspond to a feature, such as a method step, of the corresponding method. Accordingly, aspects described in relation to a method shall also be understood as a description of a corresponding block, a corresponding element, a property or a functional feature of a corresponding device or a corresponding system.

[0087] The following claims are hereby incorporated in the detailed description, wherein each claim may stand on its own as a separate example. It should also be noted that although in the claims a dependent claim refers to a particular combination with one or more other claims, other examples may also include a combination of the dependent claim with the subject matter of any other dependent or independent claim. Such combinations are hereby explicitly proposed, unless it is stated in the individual case that a particular combination is not intended. Furthermore, features of a claim should also be included for any other independent claim, even if that claim is not directly defined as dependent on that other independent claim.

Claims

1. An apparatus (100) for determining a target rotational speed for a rotary drive (130) driving a displacement pump (125) of a hydraulic system of a lifting equipment (120), the apparatus (100) comprising processing circuitry (110) configured to:

   receive first input data (101) indicating a current or planned future activation of the rotary drive (130);
   receive second input data (102) indicating a measured temperature of hydraulic fluid in the hydraulic system;
   receive third input data (103) indicating a target temperature for the hydraulic fluid;
   determine, in response to receiving the first input data (101), the target rotational speed for the rotary drive (130) based on the measured temperature and the target temperature; and
   output control data (107) indicating the determined target rotational speed.

2. The apparatus (100) of claim 1, wherein, if the measured temperature is less than the target temperature, the processing circuitry (110) is configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature.

3. The apparatus (100) of claim 1, wherein:

   if the first input data indicate a planned future activation of the rotary drive (130), the processing circuitry (110) is configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature by the time of the planned future activation of the rotary drive (130); and
   if the first input data indicate a current activation of the rotary drive (130), the processing circuitry (110) is configured to determine the target rotational speed to cause instantaneous heating of the hydraulic fluid to the target temperature.

4. The apparatus (100) of any one of claims 1 to 3, wherein the processing circuitry (110) is further configured to receive fourth input data (104) indicating a demanded rotational speed of the rotary drive (130) for operation of the lifting equipment (120), and wherein the processing circuitry (110) is configured to determine the target rotational speed based on the demanded rotational speed.

5. The apparatus (100) of claim 4, wherein, if the measured temperature is less than the target temperature, the processing circuitry (110) is configured to determine the target rotational speed to be higher than the demanded rotational speed to cause heating of the hydraulic fluid to the target temperature.

6. The apparatus (100) of claim 5, wherein the processing circuitry (110) is further configured to receive fifth input data (105) indicating a predefined rota-

tional speed offset, and wherein the processing circuitry (110) is configured to increase the demanded rotational speed by the predefined rotational speed offset to determine the target rotational speed.

7. The apparatus (100) of claim 5, wherein the processing circuitry (110) is further configured to dynamically determine a rotational speed offset based on the difference between the measured temperature and the target temperature, and wherein the processing circuitry (110) is configured to increase the demanded rotational speed by the rotational speed offset to determine the target rotational speed.

8. The apparatus (100) of any one of claims 5 to 7, wherein the processing circuitry (110) is configured to determine the target rotational speed to be higher than the demanded rotational speed until the measured temperature reaches the target temperature.

9. The apparatus (100) of any one of claims 5 to 8, wherein the processing circuitry (110) is configured to determine the target rotational speed to be the demanded rotational speed once the measured temperature has reached the target temperature.

10. The apparatus (100) of any one of claims 4 to 9, wherein, if the measured temperature is equal to or higher than the target temperature, the processing circuitry (110) is configured to determine the target rotational speed to be the demanded rotational speed.

11. The apparatus (100) of any one of claims 1 to 10, wherein the processing circuitry (110) is further configured to receive sixth input data (106) indicating a hysteresis range for the target temperature, and wherein the processing circuitry (110) is configured to determine the target rotational speed further based on the hysteresis range.

12. The apparatus (100) of any one of claims 1 to 11, wherein the processing circuitry (110) is further configured to cause output of status data to a remote control of the lifting equipment (120) or a user device of an operator of the lifting equipment (120), the status data indicating information related to at least one of the temperature of the hydraulic fluid and the determined target rotational speed.

13. The apparatus (100) of any one of claims 1 to 12, wherein the first input data (101) indicate a current activation of the rotary drive (130), and wherein the processing circuitry (110) is configured to receive the first input data from circuitry of a vehicle having mounted thereon or being the lifting equipment (120).

14. The apparatus (100) of any one of claims 1 to 12, wherein the first input data (101) indicate a planned future activation of the rotary drive (130), and wherein the processing circuitry (110) is configured to receive the first input data from a computing cloud communicatively coupled to the apparatus (100).

15. A vehicle (300) having mounted thereon or being a lifting equipment (320), wherein the vehicle (300) comprises the apparatus (100) according to any one of claims 1 to 14, wherein control circuitry (310) on the vehicle is configured to control the rotary drive (130) based on the control data (107), and wherein the hydraulic system comprises at least one of one or more hydraulic cylinders (321, 322, 323, 325) and one or more slewing drives (328) coupled to the displacement pump (125) and drivable by the hydraulic fluid.

Amended claims in accordance with Rule 137(2) EPC.

1. An apparatus (100) for determining a target rotational speed for a rotary drive (130) driving a displacement pump (125) of a hydraulic system of a lifting equipment (120), the apparatus (100) comprising processing circuitry (110) configured to:

receive first input data (101) indicating a current or planned future activation of the rotary drive (130);
receive second input data (102) indicating a measured temperature of hydraulic fluid in the hydraulic system;
receive third input data (103) indicating a target temperature for the hydraulic fluid;
receive fourth input data (104) indicating a demanded rotational speed of the rotary drive (130) for operation of the lifting equipment (120);
determine, in response to receiving the first input data (101), the target rotational speed for the rotary drive (130) based on the demanded rotational speed, the measured temperature and the target temperature, wherein, if the measured temperature is less than the target temperature, the processing circuitry (110) is configured to determine the target rotational speed to be higher than the demanded rotational speed to cause heating of the hydraulic fluid to the target temperature; and
output control data (107) indicating the determined target rotational speed.

2. The apparatus (100) of claim 1, wherein, if the measured temperature is less than the target temperature, the processing circuitry (110) is configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature.

3. The apparatus (100) of claim 1, wherein:

if the first input data indicate a planned future activation of the rotary drive (130), the processing circuitry (110) is configured to determine the target rotational speed to cause heating of the hydraulic fluid to the target temperature by the time of the planned future activation of the rotary drive (130); and
if the first input data indicate a current activation of the rotary drive (130), the processing circuitry (110) is configured to determine the target rotational speed to cause instantaneous heating of the hydraulic fluid to the target temperature.

4. The apparatus (100) of any one of claims 1 to 3, wherein the processing circuitry (110) is further configured to receive fifth input data (105) indicating a predefined rotational speed offset, and wherein the processing circuitry (110) is configured to increase the demanded rotational speed by the predefined rotational speed offset to determine the target rotational speed.

5. The apparatus (100) of any one of claims 1 to 3, wherein the processing circuitry (110) is further configured to dynamically determine a rotational speed offset based on the difference between the measured temperature and the target temperature, and wherein the processing circuitry (110) is configured to increase the demanded rotational speed by the rotational speed offset to determine the target rotational speed.

6. The apparatus (100) of any one of claims 1 to 5, wherein the processing circuitry (110) is configured to determine the target rotational speed to be higher than the demanded rotational speed until the measured temperature reaches the target temperature.

7. The apparatus (100) of any one of claims 1 to 6, wherein the processing circuitry (110) is configured to determine the target rotational speed to be the demanded rotational speed once the measured temperature has reached the target temperature.

8. The apparatus (100) of any one of claims 0 to 7, wherein, if the measured temperature is equal to or higher than the target temperature, the processing circuitry (110) is configured to determine the target rotational speed to be the demanded rotational speed.

9. The apparatus (100) of any one of claims 1 to 8, wherein the processing circuitry (110) is further configured to receive sixth input data (106) indicating a hysteresis range for the target temperature, and wherein the processing circuitry (110) is configured to determine the target rotational speed further based on the hysteresis range.

10. The apparatus (100) of any one of claims 1 to 9, wherein the processing circuitry (110) is further configured to cause output of status data to a remote control of the lifting equipment (120) or a user device of an operator of the lifting equipment (120), the status data indicating information related to at least one of the temperature of the hydraulic fluid and the determined target rotational speed.

11. The apparatus (100) of any one of claims 1 to 10, wherein the first input data (101) indicate a current activation of the rotary drive (130), and wherein the processing circuitry (110) is configured to receive the first input data from circuitry of a vehicle having mounted thereon or being the lifting equipment (120).

12. The apparatus (100) of any one of claims 1 to 10, wherein the first input data (101) indicate a planned future activation of the rotary drive (130), and wherein the processing circuitry (110) is configured to receive the first input data from a computing cloud communi-catively coupled to the apparatus (100).

13. A vehicle (300) having mounted thereon or being a lifting equipment (320), wherein the vehicle (300) comprises the apparatus (100) according to any one of claims 1 to 12, wherein control circuitry (310) on the vehicle is configured to control the rotary drive (130) based on the control data (107), and wherein the hydraulic system comprises at least one of one or more hydraulic cylinders (321, 322, 323, 325) and one or more slewing drives (328) coupled to the displacement pump (125) and drivable by the hydraulic fluid.

14. A method (400) for determining a target rotational speed for a rotary drive driving a displacement pump of a hydraulic system of a lifting equipment, the method (400) comprising:

receiving (402) first input data indicating an activation or a planned future activation of the rotary drive;
receiving (404) second input data indicating a measured temperature of hydraulic fluid in the hydraulic system;
receiving (406) third input data indicating a target temperature for the hydraulic fluid;
receiving fourth input data indicating a demanded rotational speed of the rotary drive for operation of the lifting equipment;
determining (408), in response to receiving the first input data, the target rotational speed for the rotary drive based on the demanded rotational

speed, the measured temperature and the target temperature, wherein, if the measured temperature is less than the target temperature, the target rotational speed is determined to be higher than the demanded rotational speed to cause heating of the hydraulic fluid to the target temperature; and

outputting (410) control data indicating the determined target rotational speed.

15. A program having a program code for performing the method according to claim 14, when the program is executed on a processor or a programmable hardware.

FIG. 1

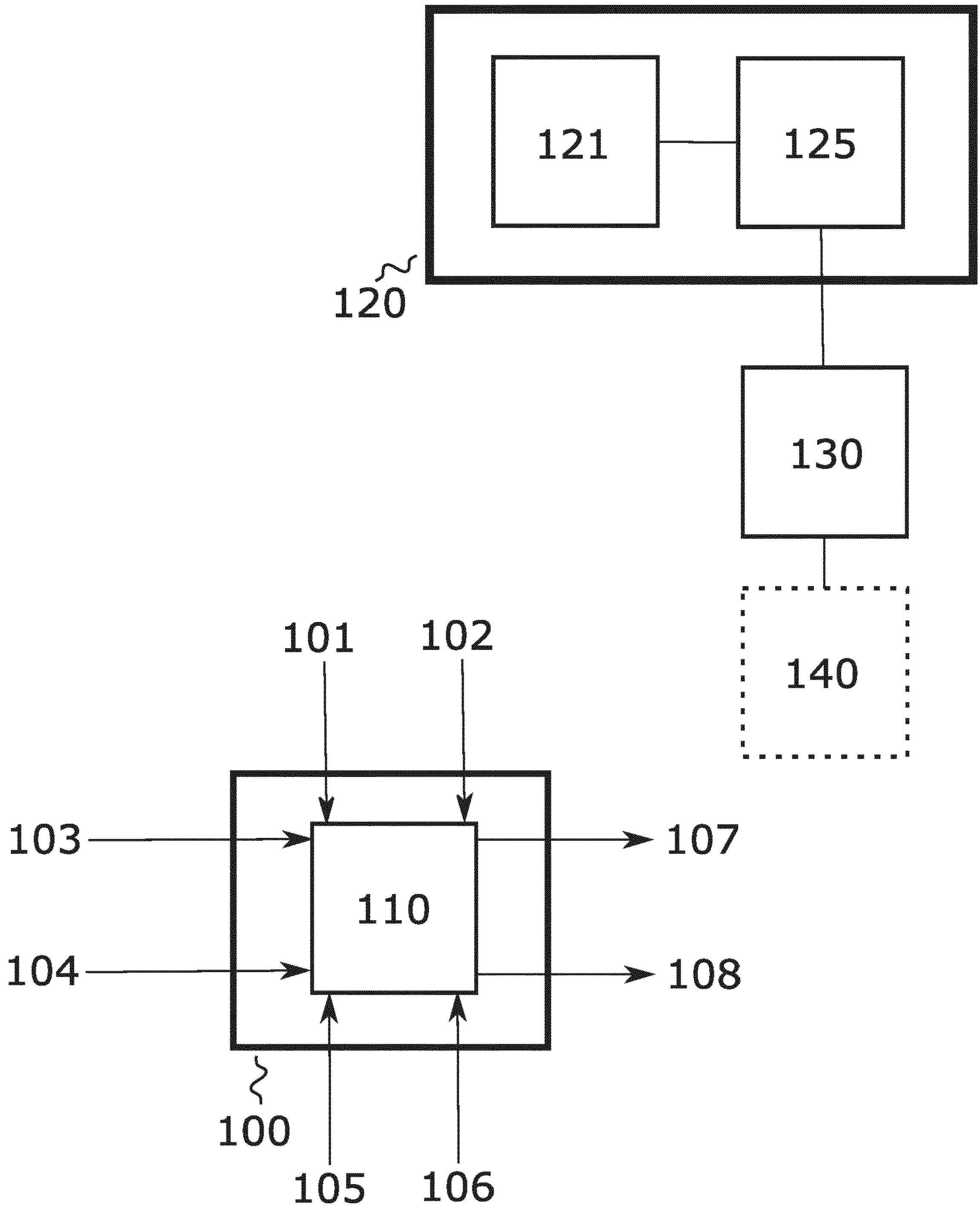

FIG. 2

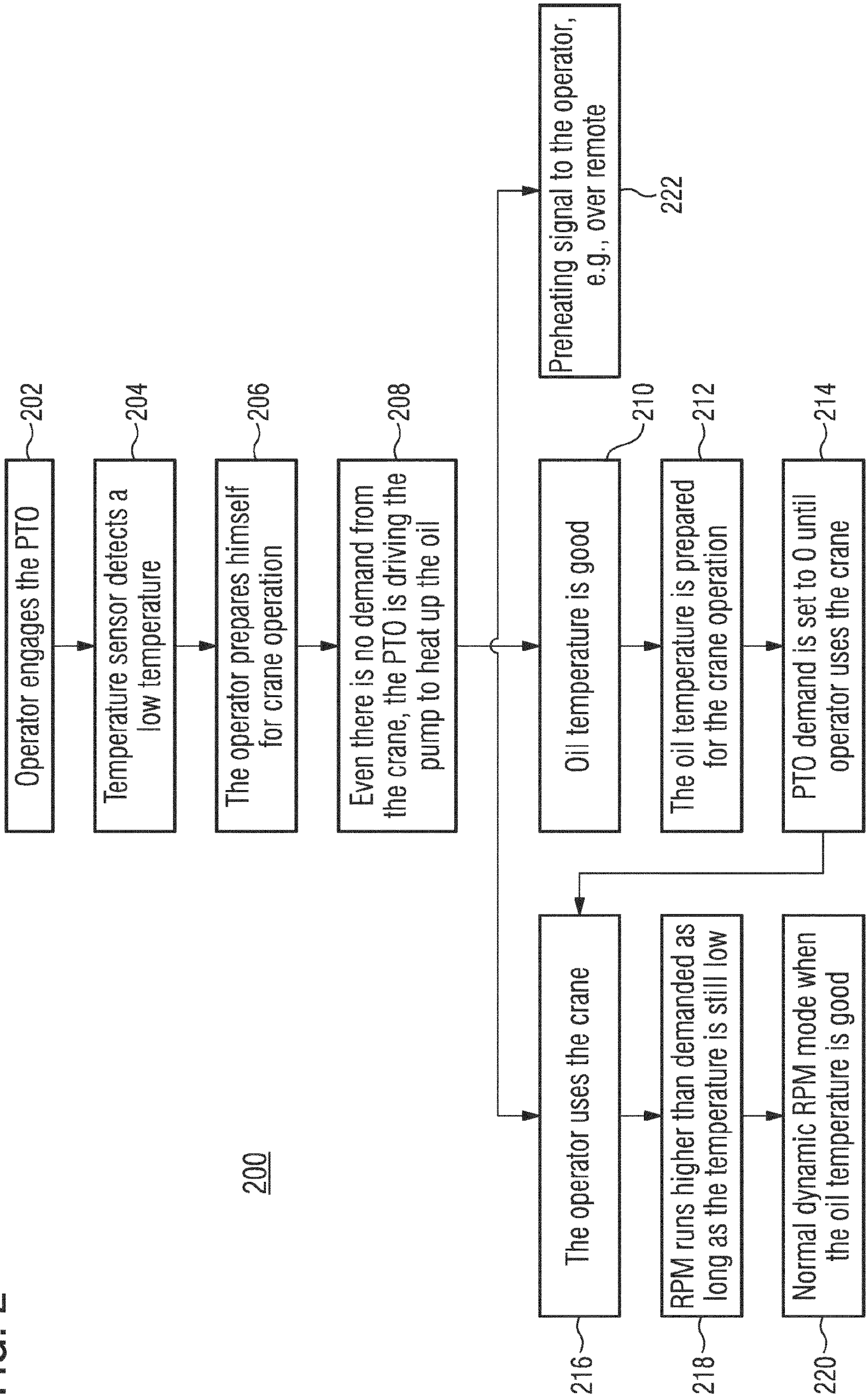
200
Operator engages the PTO
202
Temperature sensor detects a low temperature
204
The operator prepares himself for crane operation
206
Even there is no demand from the crane, the PTO is driving the pump to heat up the oil
208
Preheating signal to the operator, e.g., over remote
222
Oil temperature is good
210
The oil temperature is prepared for the crane operation
212
PTO demand is set to 0 until operator uses the crane
214
The operator uses the crane
216
RPM runs higher than demanded as long as the temperature is still low
218
Normal dynamic RPM mode when the oil temperature is good
220

FIG. 3

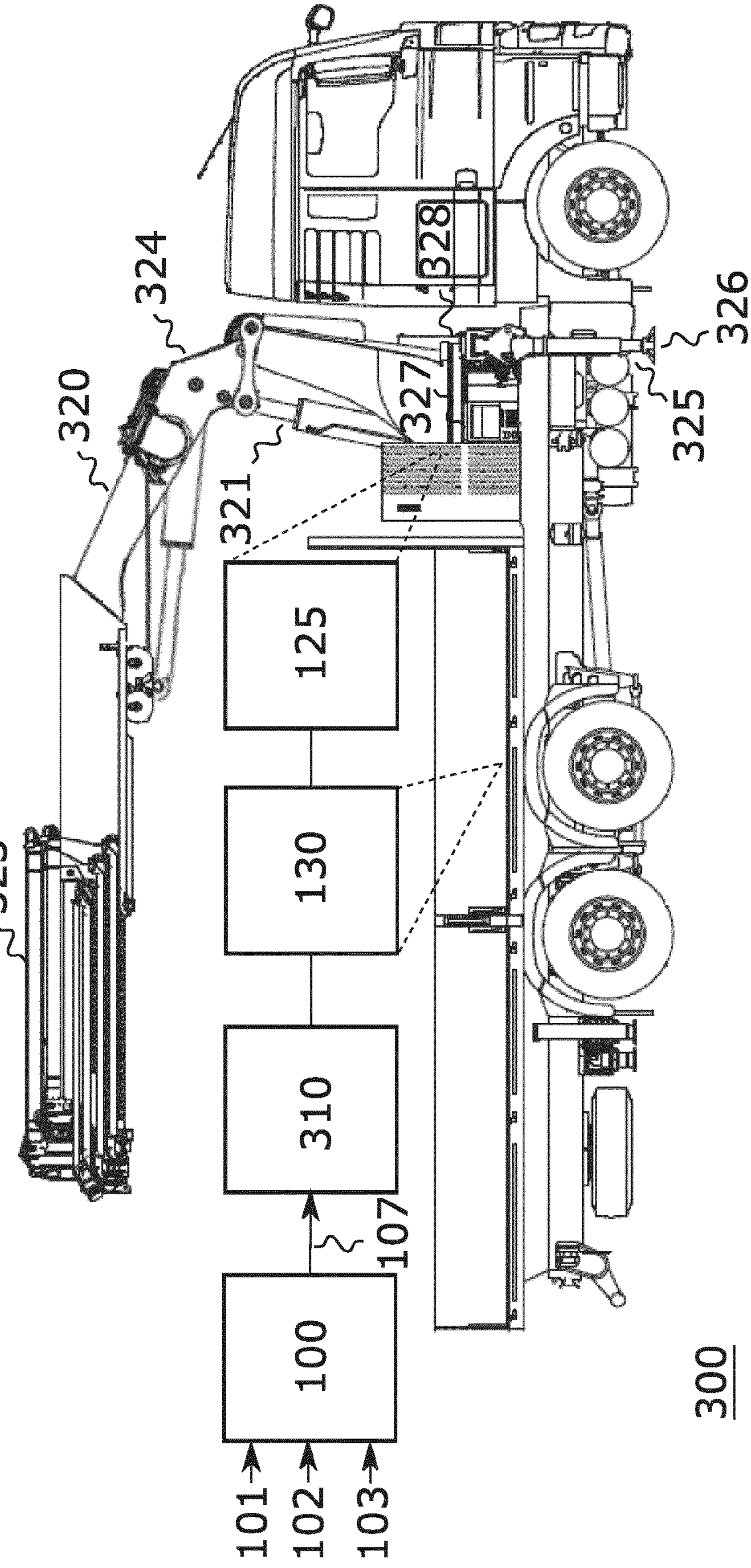
101
102
103
100
107
310
130
125
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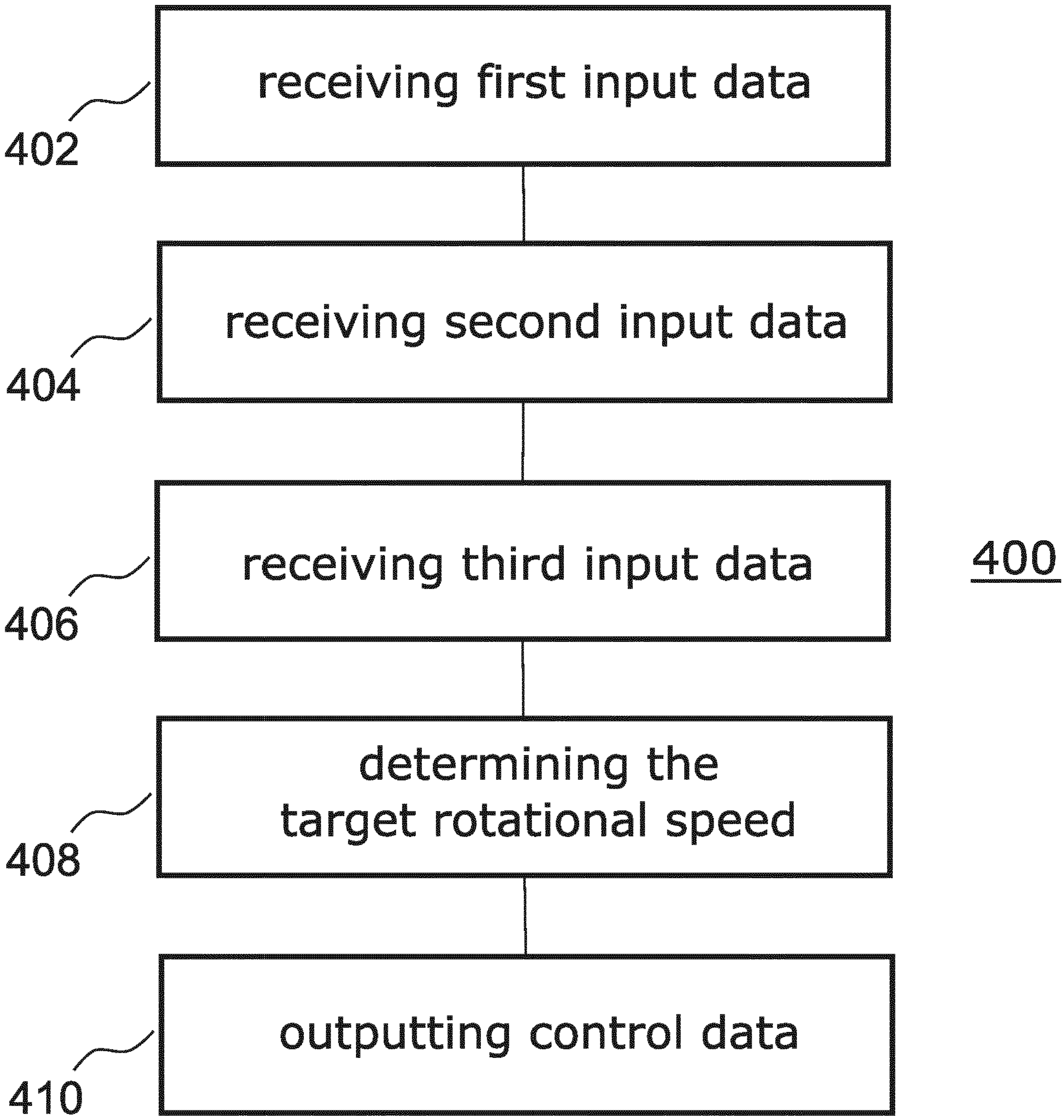
FIG. 4


receiving first input data
402
receiving second input data
404
receiving third input data
406
400
determining the target rotational speed
408
outputting control data
410

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EUROPEAN SEARCH REPORT

Application Number
EP 24 18 9511

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The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	12 December 2024	Deligiannidis, N

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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