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(54) **WORKING EQUIPMENT WITH A HYDRAULICALLY OPERATED ARM ARRANGEMENT, AND A METHOD RELATED TO THE WORKING EQUIPMENT**

(57) A working equipment (2) comprising a hydraulically movable arm arrangement (4) comprising two or more movable arm members (6) having an arm member configuration, and which are articulately connected to each other via arm member connections (8), and having associated connection functions, and an arm member tip (10); a plurality of actuators (12), arranged to be operated by hydraulic fluid discharged from at least one hydraulic pump (14); a sensor system (16), and an equipment controller (18) configured to receive arm member tip commands (20), comprising characteristics of wanted movements of the arm member tip (10), receive signals (22) from the sensor system (16), to e.g. determine and monitor current position of the arm member tip (10), and

to control movements of the two or more arm members (6) in accordance with the received arm member tip commands (20), by generating and applying operating signals (24) controlling the flow and/or pressure of hydraulic fluid to the plurality of actuators (12).

The equipment controller (18) is further arranged to monitor the required flow of hydraulic fluid from the at least one pump (14) for the movements of the movements of the two or more arm members (6) and to apply an adaption rule to maintain the required flow below a predetermined maximum flow limit and to comply with the received arm member tip command (20) when generating the operating signals (24)..

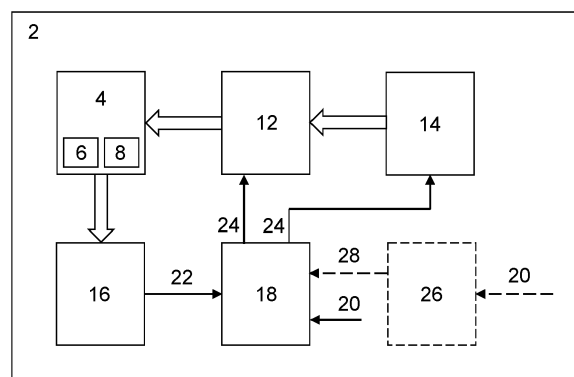


FIG. 2

DescriptionTechnical field

- 5 **[0001]** The present disclosure relates to a working equipment, e.g. a crane mounted to a vehicle, comprising a hydraulically operated arm arrangement. Specifically, it is disclosed a working equipment provided with an improved control of movements of an arm member tip in particular with regard to velocity.

Background

- 10 **[0002]** Generally, the invention relates to the field of hydraulics, and motion control. It provides an improved solution for controlling e.g. the arm member tip velocity to ensure that maximised arm member tip velocity can be achieved and still remain within available pump flow provided by one or more hydraulic pump(s) of the working equipment comprising a hydraulically operated arm arrangement.

- 15 **[0003]** Below are listed references that disclose working equipment comprising a plurality of sensors for sensing crane boom positions/fluid flows and a controller for controlling hydraulic actuators of a crane.

[0004] US20210231140A1 discloses a method of controlling the movement of a boom of a work machine, wherein the work machine comprises a plurality of booms which are articulately connected to each other, a plurality of sensors for monitoring the position of the boom and a controller to control the hydraulic fluid flow.

- 20 **[0005]** EP4086216A1 discloses a crane that is arranged to be mounted to a vehicle which comprises a crane boom system consisting of hydraulic actuators to perform movements according to operating signals, a sensor system to monitor boom position and crane operating conditions and a control unit configured to estimate a required flow level of each of the hydraulic actuators for the wanted movements of the crane components. US6498973B2 discloses a work vehicle provided with several hydraulic actuators in a system and method for controlling and scaling flow between the actuators. The system includes an electronic controller that is connected to several hand controls that provide a proportional signal indicating how far the operator has moved the hand controls. The controller reads the hand controls and proportionally scales the total available flow to make sure the operator does not demand too much fluid from the hydraulic pump.

- 25 **[0006]** In crane operation, the simplest form of crane tip control (CTC), also called boom tip control, the operator input is applied to move the crane tip in vertical or horizontal directions, or a combination of both. Performing a full remote control lever stroke for horizontal movement, means a motion of the crane tip in horizontal direction with full speed. The CTC or boom tip control offers an alternative control methodology to the standard crane arm control methodology where the movement of the booms of the crane are controlled individually for each boom, by the crane operator via e.g. the operator's remote control unit. The following illustrative example can be made for a loader crane comprising a rotatable crane column with a first boom pivotally attached to the crane column and in turn a second boom pivotally mounted to the first boom, where the second boom further has telescopically extendable and retractable boom extensions. The standard crane control methodology would then imply that the crane operator controls the rotation (also referred to the slewing angle) of the crane column with one lever of the remote control unit, the pivoting angle of the first boom relative to the crane column with another lever, the pivoting angle of the second boom relative to the first boom with another lever and the retraction and extension of the telescopic boom extensions of the second boom with yet another lever. All lever strokes are hence also affecting the crane tip indirectly but the crane tip in itself is in this example not directly controlled by the operator via the remote control unit.

- 30 **[0007]** In a presently applied control method, a CTC algorithm will convert the wanted crane tip motion of a crane arm, with several booms, into small steps, and tries to achieve those small steps within a fixed time interval, such as within a sample time and calculates what is the crane joint positions of the booms of the crane arm positions of the booms of the crane arm in the next interval. The difference between desired and current joint positions is used to calculate the required flow for each boom, which is systematically proportional to a certain velocity in time that a crane can achieve. If we again go back to the previously explained illustrative example of a loader crane, the rotatable connection of the crane column to a base of the loader crane is one example of a joint and the rotation angle (sometimes referred to as a slewing angle) would be the respective joint position. Similarly, the pivoting connection of the first boom to the crane column and the pivoting connection of the second boom to the first boom would also be further examples of joints with their respective pivoting angles being further examples of pivoting positions. In this context and example, the telescopic extension of the second boom is a further example of a joint with the extension length of the telescopic boom being an example of a joint position.

- 35 **[0008]** In some of the presently applied implementations, the crane tip velocity is specified as a constant parameter in the system. This means that the total flow needed for the movement of the crane tip in each step may be varying, and if the crane tip velocity is set to a relatively high value that cannot be reached due the actual flow limitation of the crane, a pump flow distribution (PFD) control feature will typically scale the crane functions, i.e. here the individual boom movements, so that the crane functions do not demand more flow than is provided by the pump by distributing the available flow to each function, typically in an equal manner. This may result in loss of crane tip position accuracy. For example, a crane tip will not

be able follow a straight line within an error tolerance, and may move along a sinusoidal trajectory with a low frequency.

[0009] Specifying a well-balanced parameter for the crane tip velocity is a time-consuming task in these implementations and does not guarantee an optimised solution that can provide maximum crane tip velocity and position accuracy.

[0010] An articulated system, such as a loader crane, is composed of different angular and prismatic joints, such as slew, first boom and second boom as revolute joints and second boom extension is a prismatic joint. The maximum crane tip velocity is dependent on the joint position configuration and joint velocities.

[0011] For example, if slew, first boom and second boom are positioned at 0 degree, and second boom extension joint is operated at 100% speed, then the crane tip velocity will be directly proportional to second boom extension joint velocity in m/s.

[0012] But if instead a straight line for crane tip movement should be followed using a combination of either of (1) a first and second boom movements, or (2) second boom and second boom extension movements, or (3) first boom and second boom movements, then the crane tip velocity will depend on the joint positions and their respective velocities.

[0013] Considering the above discussion, it is observed that the maximum crane tip velocity is not a fixed value and cannot be defined using a fixed value, and that modified crane function commands from a proper regulator will override the commands, but there is no guarantee that the joints will be able to move to the desired position.

[0014] The object of the present invention is to achieve an improved control of arm member tip movements specifically to achieve higher arm member tip velocity, improved accuracy, and/or improved energy efficiency.

Summary

[0015] The above-mentioned objects are achieved by the present invention according to the independent claims.

[0016] Preferred embodiments are set forth in the dependent claims.

[0017] The present invention is intended to provide a technical solution to determine an improved control of arm member tip movements that considers each arm member connection velocity limits and available pump flow for the working equipment.

[0018] According to the technical solution, the arm member tip velocity is planned in a way such that the highest possible arm member tip velocity is achieved by considering the pump flow available for the movable arm arrangement of the working equipment and current arm member connection configuration before calculating the next desired arm member connection position.

[0019] Implementing the present invention makes it possible to control the pump flow distribution prioritisation based on the presently applied optimization goal such as maximising the crane tip velocity or position accuracy or energy efficiency, e.g. by scaling the crane tip velocity up/down based on the available pump flow, and crane joint configuration.

[0020] Instead of moving the arm member tip a predetermined distance during a sample, the moved distance instead is adapted to the available hydraulic flow, which may result in that a shorter movement distance but at the same speed.

[0021] The arm member tip velocity is planned in dependence of the available hydraulic flow. In order to achieve this planning, the capabilities, e.g. the position, of each arm member connection are determined, i.e. by determining the angle and length/extension, then the velocity of arm member connection movement is estimated, and based upon that, the flow required is estimated for each arm member connection. This information is combined in order to determine the tip velocity. Important aspects when combining this information are e.g. the configuration of the arm member connections, and scaling up/down various calculated parameters. If an adaption rule directed to achieve a maximum arm member tip velocity is applied, the maximum velocity is adapted to available hydraulic flow. Thereby, smooth movements of arm member tip will be achieved.

[0022] The present invention is also applicable for semi- or fully autonomous systems.

[0023] Thus, instead of an operator controlling the equipment controller via a remote control unit, the equipment controller may instead be controlled by an autonomous control unit.

Brief description of the drawings

[0024]

Figure 1 is a schematic illustration of a vehicle provided with a working equipment according to the present invention.

Figure 2 is a block diagram that schematically illustrates the present invention.

Figure 3 shows an exemplary relationship between a first boom velocity and a lever command according to one embodiment.

Figure 4 shows a block diagram that schematically illustrates an embodiment of the present invention.

Figure 5 is a flow diagram illustrating the method according to the present invention.

Detailed description

[0025] The working equipment will now be described in detail with references to the appended figures. Throughout the figures the same, or similar, items have the same reference signs. Moreover, the items and the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0026] With references to figures 1 and 2, the present invention relates to a working equipment 2, e.g. a crane mounted on a vehicle 1, comprising a hydraulically movable arm arrangement 4, comprising two or more movable arm members 6 having an arm member configuration. The movable arm members are articulately and/or telescopically connected to each other via arm member connections 8, such as arm member joints and telescopic boom extensions, and having associated connection functions. The arm arrangement is provided with an arm member tip 10 at a free end of the utmost of the two or more movable arm members 6.

[0027] Herein, the expression arm member connection function generally is used to represent various crane functions such as slew of a crane arm member such as a crane column, pivoting of a first boom of a crane relative to its crane column, pivoting of a second boom of a crane relative to its first boom and/or the extension and/or retraction of a telescopic boom e.g. used as a second boom or a third boom of a crane.

[0028] The working equipment further comprises a plurality of actuators 12, arranged to be operated by hydraulic fluid discharged from at least one hydraulic pump 14 and further arranged to move the two or more arm members 6 of the movable arm arrangement 4 during a working assignment, e.g. a loading/unloading procedure. In figure 2, the hydraulic fluid discharged from the at least one pump 14 to the plurality of actuators 12 and further to provide movements to the arm members 6, is indicated by block arrows. Also, a sensor system 16 is included in the working equipment, that comprises a plurality of sensors for sensing measures of various parameters of the movable arm arrangement 4. In figure 2, the sensing measures of various parameters are indicated by a block arrow from the arm arrangement 4 to the sensor system 16.

[0029] The working equipment 2 also comprises an equipment controller 18 configured to receive arm member tip commands 20, comprising characteristics of wanted movements of the arm member tip 10, such as a direction of movement for the arm member tip 10, and to receive signals 22 from the sensor system 16, to determine and monitor current position of the arm member tip 10, and one or many of relative positions of the two or more arm members 6, position configurations and movement velocities of the arm member connections 8. Additional examples of characteristics of wanted movements of the arm member tip 10 may be a parameter indicating a relative speed of the movement.

[0030] The equipment controller is also configured to control movements of the two or more arm members 6 in accordance with the received arm member tip commands 20, by generating and applying operating signals 24 controlling the flow and/or pressure of hydraulic fluid to the plurality of actuators 12. The operating signals 24 are applied to a hydraulic system controlling the supply and return of hydraulic oil to the chambers of at least some of the actuators 12. The hydraulic system comprises the hydraulic pump 14 which may be controlled by the operating signals 12 as well as other hydraulic components for controlling direction and/or flow and/or pressure of the hydraulic fluid that are supplied and returned from the chambers of at least some of the actuators 12, this includes hydraulic valves and control valves. Hydraulic components controlling the inlet and outlet at the actuators 12 may also form part of this hydraulic system.

[0031] The equipment controller 18 is further arranged to monitor the required flow of hydraulic fluid from the at least one pump 14 for the movements of the two or more arm members 6 and to apply an adaption rule to maintain the required flow below a predetermined maximum flow limit and to comply with the received arm member tip command 20 when generating the operating signals 24.

[0032] In one embodiment, the equipment controller 18 is arranged to apply an adaption rule when generating the operating signals 24 to control the flow to the plurality of actuators 12 for moving each of the two or more arm members 6. By applying the adaption rule in this embodiment, various parameters for setting the flow and/or pressure of the hydraulic fluid at the actuators 12 are scaled and prioritized, thereby resulting in smooth movements of the arm member tip 10.

[0033] The predetermined maximum flow limit is preferably equal to or less than a maximal flow of hydraulic fluid discharged from said at least one hydraulic pump 14.

[0034] In another embodiment, the adaption rule is a rule to maximise the velocity of the arm member tip 10, and the working equipment 2 is further arranged to apply the adaption rule to maximise the velocity when generating operating signals 24 to increase the required flow and comply with the received arm member tip command 20.

[0035] With references to figure 4, an illustrative example of a procedure for pump flow distribution in the context of CTC operation of a crane arm having four different joints will be described. The joints may be of any type, as earlier explained. For the sake of this example, the first joint may be the slew of the crane arm's crane column, the second joint may be the pivoting joint of the first boom connected to the crane column, the third joint may be the pivoting joint of the second boom connected to the first boom and the fourth joint may be the telescopic extension/retraction of the second boom (the second boom is here a telescopic boom). The procedure comprises a number of steps C1-C5.

[0036] C1. Conversion from joint position velocities of the four joints (these input joint position velocities being calculated according a CTC control method based on input of wanted crane tip movements) (denoted $\dot{q}_1 - \dot{q}_4$) to joint commands in % (denoted $cmd_1[\%]-cmd_4[\%]$). These joint commands are corresponding to the commands that would have been received

from a crane operator if he or she would have operated the individual joints in the same manner as was calculated using the CTC control method.

[0037] C2. Conversion of joint commands to requested flow Q in l/min (denoted Q_1 - Q_4) using oil need parameter (30) for the requested movement (positive or negative; extension or retraction of the involved actuators controlling the joints) of each of the joints.

[0038] C3. Scaling the requested flow to a scaled requested flow (denoted SQ_1 - SQ_4) and calculating accumulated flow based on available pump flow (34), joint priorities (32) and oil need parameter (30).

[0039] C4. Conversion from scaled requested flow to scaled joint commands (denoted $Scmd_1$ - $Scmd_4$).

[0040] C5. Conversion of the scaled joint commands to scaled joint velocities. This is the inverse of the conversion performed in step C1. In addition to this a PFD speed factor 38 may also be calculated and output from this procedure. The PFD speed factor 38 is calculated using an accumulated prioritized flow 36 summing the scaled requested flow from all the four joints in this example. This accumulated prioritized flow 36 is then compared to the available flow from the pump(s) and the PFD speed factor then reflects if there in fact is a possibility to increase flow consumption and thereby achieve increase the resulting speed of the crane tip. However, if the procedure is used for achieve a high precision in the crane tip position then the PFD speed factor will not be used to increase the speed of the crane tip.

[0041] As earlier explained with reference to figure 4, the oil need parameters for the wanted movements of the joints is denoted 30, joint priority function(s) is denoted 32, pump flow is denoted 34, accumulated prioritized flow is denoted 36, and the PFD speed factor is denoted 38.

[0042] The procedure for pump flow distribution in the context of CTC operation of a crane arm, described above, is an example of how an equipment controller 18 may apply an adaption rule when generating operation signals 24. In that example the adaption rule is applied to the calculated joint velocities calculated by a CTC control algorithm to achieve scaled joint velocities. The scaled joint velocities are then transformed into operation signals 24 by the equipment controller 18.

[0043] In the following, an exemplary procedure is provided to be used in order to adapt the generated operating signals 24 according to the adaption rule, the exemplary procedure essentially corresponds to the steps C1-C5 described above. Input to the procedure are joint velocities calculated through CTC, as known in the art and earlier described based on received sensor values describing current joint positions and characteristics of wanted movements received through arm members tip commands by the equipment controller 18. In this exemplary procedure, schematically described as procedure steps I-VI and with references to figure 4, the equipment controller 18 is configured to:

Step I - Convert joint velocities, calculated by using CTC, for the respective connection functions of the movable arm arrangement 4 to operating signal commands in % for all involved connection functions.

[0044] This step may be performed by estimating the relationship between these parameters for each connection function using only few parameter values:

1. Maximum $\pm$ connection function velocity at t 100%.
2. Minimum $\pm$ connection function velocity at $\pm$ deadband.

[0045] Deadband is referred as a value of a command input via e.g. a lever on a remote control unit $26 \pm X\%$ at which an arm member connection is started to move.

[0046] Given the above-mentioned parameters and joint velocities, the remote lever command is calculated as if an operator was operating each function manually.

[0047] Figure 3 shows an estimation of such a relationship for a first boom joint. The first curve S1 shows measured points at lever of remote control unit in % [$\pm 0, \pm 10, \pm 20, \pm 30, \pm 40, t50, t60, t70, t80, t90, \pm 100$] and joint velocity estimated at corresponding commands. The second curve S2 shows estimated relationship using only above-mentioned parameters. The curves essentially follow each other, i.e. this estimation is close enough to give an estimate of lever command.

[0048] Step II - Convert the operating signal commands in % to requested flows Q (e.g. in l/min), preferably in a linear manner, using a hydraulic fluid need parameter for positive or negative movement 30.

[0049] As an example, if the operating signal command to request flow is made in a linear manner, a command of 10% will request 10% of maximum flow required for a connection function.

[0050] Step III - Convert the requested flows Q to scaled flows sQ for all involved connection functions, by scaling the requested flows up/down for all involved connection functions. More specifically, as in normal PFD control feature, slew can be kept at highest priority, so that the requested slew flow will not be scaled down or up, and only do so on the rest of the connection functions. The scaling request flow down/up of each of the connection functions, can be equally distributed among all, or one or more connection functions may be prioritized.

[0051] In CTC, there are typically two functions to create a straight line other than slew. From the CTC algorithm it is known which those functions are, and the priority may be set based on optimization goals, such as maximize the crane tip velocity, or position accuracy, or energy efficiency. This is advantageous in that various possibilities may be tested and switched in/between whenever needed.

[0052] Step IV - Convert the scaled flows sQ to scaled operating signal commands, and calculate accumulated flow after scaling down the operating signal commands.

[0053] Step V - Convert scaled operating signal commands to scaled connection velocities for all involved connection functions, by applying the relationship previously discussed (see figure 3 where an exemplary relationship is shown) related to respective arm member connection as an inverse function given the scaled operating signal command.

[0054] Step VI - Apply adaption rule to achieve the determined scaled connection velocities for all involved connection functions.

[0055] The scaling in step III of the requested flows up/down for all involved connection functions is performed either by equally distributing the flow between all involved connection functions, or by prioritising one or more of the involved connection functions, based upon the optimization goal of the adaptation rule. If needed to comply with the received arm member tip command for e.g. linear tip movements this may further be considered in the scaling and/or prioritization.

[0056] In one variation of the above procedure, the accumulated flow is calculated based on summing the scaled flows sQ of the different connection functions. The equipment controller 8 is then further arranged to calculate an accumulated flow speed factor 38 for the involved connection functions, and based on priority of speed factor, either increase or decrease the arm member tip velocity.

[0057] Various exemplary embodiments and variations will be discussed in the following.

[0058] In addition to scaling down the arm member connection velocity, it may also be possible to calculate a so-called PFD Speed Factor (ref. 38 in figure 4) using the following equation (Equation 1):

$$PFD\text{SpeedFactor} = 100 - (AccumPriorFlow/PumpFlow) * 100$$

[0059] If the total accumulated pump flow after the scaling is still less than the total available pump flow then it may also be calculated (in percentage) how much is remaining and adding more speed to the arm member tip velocity in order to always maximise the usage of the available pump flow.

[0060] If instead it is required to increase the arm member tip position precision, this extra speed factor may be disabled.

[0061] Taking an example with a loader crane, a first connection function may be the slew of the crane arm's crane column, a second connection function may be the pivoting joint of the first boom connected to the crane column, a third connection function may be the pivoting joint of the second boom connected to the first boom and a fourth connection function may be the telescopic extension/retraction of the second boom (the second boom is here a telescopic boom). The crane tip velocity in X, Y and Z coordinates may for this example be calculated using following equation (Equation 2):

$$\begin{aligned}\dot{\chi}_{TipVelX} &= -\dot{q}_1(\sin(q_1)(a_2\cos(q_2) + (a_3 + q_4)\cos(q_2 + q_3))) + \\ &\quad \dot{q}_2(\cos(q_1)(-a_2\sin(q_2) - (a_3 + q_4)\sin(q_2 + q_3))) - \\ &\quad \dot{q}_3(\sin(q_2 + q_1)\cos(q_1)(a_3 + q_4)) + \dot{q}_4(\cos(q_1)\cos(q_2 + q_3)) \\ \dot{\chi}_{TipVelY} &= \dot{q}_1(\cos(q_1)(a_2\cos(q_2) + (a_3 + q_4)\cos(q_2 + q_3))) + \\ &\quad \dot{q}_2(\sin(q_1)(-a_2\sin(q_2) - (a_3 + q_4)\sin(q_2 + q_3))) - \\ &\quad \dot{q}_3(\sin(q_1)(a_3 + q_4)\sin(q_2 + q_3)) + \dot{q}_4(\sin(q_1)\cos(q_2 + q_3)) \\ \dot{\chi}_{TipVelZ} &= \dot{q}_2(a_2\cos(q_2) + (a_3 + q_4)\cos(q_2 + q_3)) + \\ &\quad \dot{q}_3((a_3 + q_4)\cos(q_2 + q_3)) + \\ &\quad \dot{q}_4(\sin(q_2 + q_3))\end{aligned}$$

Equation 2

where,

- q_1 is slew arm member connection angle in radians,
- q_2 is first boom arm member connection in radians,
- q_3 is second boom arm member connection angle in radians,
- q_4 is second boom extension arm member connection position in meters,
- $\dot{q}_1$ is first boom arm member connection velocity in radians/s
- $\dot{q}_2$ is slew arm member connection velocity in radians/s
- $\dot{q}_3$ is second boom arm member connection velocity in radians/s

- $q4_dot$ is second boom extension arm member connection velocity in m/s

[0062] Calculations of Crane Tip Velocity Factor with PFD Scaled arm member connection velocities:

Given arm member connection positions measurements and scaled arm member connection velocities by CTCPPD, the new crane tip velocity is calculated using Equation 2 that is in meter/second, and it is possible to convert that into meter per interval by multiplying with system sample time (Δt). See equation 3:

$$\begin{bmatrix} CraneTipXFactor_{calc} \\ CraneTipYFactor_{calc} \\ CraneTipZFactor_{calc} \end{bmatrix} = \begin{bmatrix} \left(\frac{\dot{X}_{TipVelX} \cdot \Delta t}{100} \right) \\ \left(\frac{\dot{X}_{TipVelY} \cdot \Delta t}{100} \right) \\ \left(\frac{\dot{X}_{TipVelZ} \cdot \Delta t}{100} \right) \end{bmatrix}$$

Equation 3

[0063] Calculations of Maximum Crane Tip Velocity Factor:

The maximum crane tip velocity can be set using a parameter called *TipMaxVelParam* that allows user to specify maximum velocity limit that is in meter per second, and it is possible to convert that into meter per interval by multiplying with system sample time (Δt). See equation 4:

$$\begin{aligned} XLimitMax &= TipMaxVelParam \cdot \frac{\Delta t}{100} \\ YLimitMax &= TipMaxVelParam \cdot \frac{\Delta t}{100} \\ ZLimitMax &= TipMaxVelParam \cdot \frac{\Delta t}{100} \end{aligned}$$

Equation 4

[0064] Calculations of Minimum Crane Tip Velocity Factor:

A fixed minimum crane tip velocity factor cannot be set to zero, and it is therefore assumed that it is equal to the 50% of maximum crane tip velocity factor. This does not guarantee that this assumption is correct. What is guaranteed is that if *TipMaxVelParam* is less than or equal to second boom extension arm member connection velocity in m/s, an improvement is identified. And this factor cannot be set equal to zero, because in this case, the crane tip might never move. To overcome this, a PFD speed factor is determined and used as described in the following equation (Equation 5):

$$\begin{aligned} XLimitMin &= XLimitMinFixed + XLimitMinFixed \cdot \frac{PFDSpeedFactor}{100} \\ YLimitMin &= YLimitMinFixed + YLimitMinFixed \cdot \frac{PFDSpeedFactor}{100} \\ ZLimitMin &= ZLimitMinFixed + ZLimitMinFixed \cdot \frac{PFDSpeedFactor}{100} \end{aligned}$$

Equation 5

[0065] Where

$$\begin{aligned} XLimitMinFixed &= \frac{XLimitMax}{2} \\ YLimitMinFixed &= \frac{YLimitMax}{2} \\ ZLimitMinFixed &= \frac{ZLimitMax}{2} \end{aligned}$$

[0066] If an operator desires precision in positions over speed, then it is possible to disable this additional speed factor

PFD. The tip will then move step-wise as fast as possible given present joint configuration, velocities and available pump flow.

[0067] According to another embodiment, the adaption rule is:

- a rule to maximise the velocity of the arm member tip 10, or
- a rule to prioritise the accuracy of the position of the arm member tip 10, or
- a rule to prioritise the energy efficiency in the movement of the arm member tip 10.

[0068] The rule to prioritize accuracy is applied if not the speed factor is used to scale up the velocity of the arm member tip 10 as much as possible.

[0069] The rule to prioritize energy efficiency would for example be based on which crane functions to give priority to, and which functions to allow operating at the same time, to reduce the operating time with functions having a mismatch in the pressure and/or flow, when operating with a single pump system, or other strategies to minimize or optimize the energy consumption of the movements of an arm arrangement.

[0070] The working equipment preferably further comprises a remote control unit 26, e.g. a handheld remote control unit, configured to receive the arm member tip commands 20 of wanted arm member tip movements from an operator and to transmit the arm member tip commands 20 as arm member tip command signals 28 to the equipment controller 18. This embodiment is shown by dashed lines in figure 2. The remote control unit 26 may further be configured to receive an adaption rule command from the operator by selecting one of the at least one adaption rule to be applied by the equipment controller 18. As an example, the adaption rule may alternatively be activated, added, selected and/or enabled as part a configuration procedure of the equipment controller 18.

[0071] In a preferred application, the hydraulically movable arm arrangement 4 is a crane arm arrangement comprising one or many crane booms, telescopic booms, and crane boom extensions, that preferably is mounted to a vehicle 1, such as a truck. The crane arm arrangement 4 may also be arranged to be mounted to any other object, e.g. a boat, a building, a wind turbine.

[0072] The crane arm members 6 includes the arm member tip 10 arranged at a free end of an outermost crane boom.

[0073] More particularly, the arm members 6 may comprise a crane column arranged to rotate, or slew, around a vertical axis perpendicular to the plane of the vehicle, a first (inner) boom connected to the crane column, and a second (outer) telescopic boom connected to the first boom and provided with one or more extensions. Additional components, such as additional telescopic booms (also referred to as jibs) or crane tool may form part of the crane components.

[0074] Furthermore, the working equipment comprises hydraulic actuators 12 arranged to be operated by hydraulic fluid having a hydraulic flow, where the hydraulic fluid being discharged from the at least one hydraulic pump 14. The hydraulic actuators are further arranged to apply movements to the crane arm arrangement such that the crane tip 10 is moved from a current position to a target position in response to received operating signals 24.

[0075] The crane also comprises a sensor system 16 configured to monitor current positions of the crane components, and to generate sensor signals 22 in response to the monitored current positions and operating conditions.

[0076] Thus, the sensor system is configured to monitor current positions of the crane components, and comprises sensors arranged to measure e.g. an angle of a crane boom compared to a reference plane, or the extension length of the telescopic boom (individual extension of a boom extension or the extension of the telescopic boom as a whole). The sensor system is also configured to monitor the operating conditions of the system of the hydraulic actuators and the hydraulic pump, and to generate sensor signals in response to measured pressures and flows at specific parts of the hydraulic system. The sensor system is hence used to monitor current positions and operating conditions of the crane.

[0077] The present invention also relates to a method of a working equipment 2 arranged to be mounted to e.g. a vehicle 1. The working equipment has been described in detail above and it is herein referred to that description. The method will now be described with references to the flow diagram shown in figure 5.

[0078] Thus, the method comprises:

- receiving arm member tip commands 20, comprising characteristics of wanted movements of the arm member tip 10, such as a direction of movement for the arm member tip 10;
- receiving signals 22 from the sensor system 16, to determine and monitor current position of the arm member tip 10, one or many of relative positions of the two or more arm members 6, and position configurations and movement velocities of the arm member connections 8,
- controlling movements of the two or more arm members 6 in accordance with the received arm member tip commands 20, by generating and applying operating signals 24 controlling the flow and/or pressure of hydraulic fluid to the plurality of actuators 12.

[0079] The method further comprises, monitoring, by the equipment controller 18, the required flow of hydraulic fluid from the at least one pump 14 for the movements of the two or more arm members 6 and applying an adaption rule to

maintain the required flow below a predetermined maximum flow limit and to comply with the received arm member tip command 20, when generating the operating signals 24.

[0080] In the following, some embodiments of the method are listed. In the flow diagram, embodiments are shown within dashed lines. These embodiments have the same technical features and advantages as for the corresponding features of the working equipment described above. Consequently, these technical features and advantages are not repeated or explained anew in order to avoid unnecessary repetition.

[0081] In one embodiment, the method comprises applying said adaption rule when generating the operating signals 24 to control the flow to the plurality of actuators 12 for moving each of the two or more arm members 6 by scaling, and prioritizing parameters in calculations performed when applying said adaption rule, thereby resulting in smooth movements of said arm member tip 10.

[0082] In a further embodiment, the predetermined maximum flow limit is equal to or less than a maximal flow of hydraulic fluid discharged from the at least one hydraulic pump 14.

[0083] In another embodiment, the adaption rule is a rule to maximise the velocity of the arm member tip 10, and the method then comprises applying said adaption rule to maximise the velocity when generating operating signals 24 to increase the required flow and comply with the received arm member tip command 20.

[0084] In a further embodiment, the adaption rule is:

- a rule to maximise the velocity of the arm member tip 10, or
- a rule to prioritise the accuracy of the position of the arm member tip 10, or
- a rule to prioritise the energy efficiency in the movement of the arm member tip 10.

[0085] The present invention is not limited to the above-described preferred embodiments. Various alternatives, and modifications may be used. Therefore, the above embodiments should not be taken as limiting the scope of the invention, which is defined by the appending claims.

Claims

1. A working equipment (2) comprising:

- a hydraulically movable arm arrangement (4) comprising two or more movable arm members (6) having an arm member configuration, and which are articulately connected to each other via arm member connections (8), such as arm member joints and telescopic boom extensions, and having associated connection functions, and an arm member tip (10) at a free end of the utmost of said two or more movable arm members (6);
- a plurality of actuators (12), arranged to be operated by hydraulic fluid discharged from at least one hydraulic pump (14) and further arranged to move the two or more arm members (6) of the movable arm arrangement (4) during a working assignment;
- a sensor system (16) comprising a plurality of sensors for sensing measures of various parameters of said movable arm arrangement (4), and
- an equipment controller (18) configured to:
 - receive arm member tip commands (20), comprising characteristics of wanted movements of the arm member tip (10), such as a direction of movement for the arm member tip (10),
 - receive signals (22) from the sensor system (16), to determine and monitor current position of the arm member tip (10), one or many of relative positions of the two or more arm members (6), and position configurations and movement velocities of said arm member connections (8),
 - control movements of the two or more arm members (6) in accordance with the received arm member tip commands (20), by generating and applying operating signals (24) controlling the flow and/or pressure of hydraulic fluid to the plurality of actuators (12),

characterized in that the equipment controller (18) is further arranged to monitor the required flow of hydraulic fluid from the at least one pump (14) for the movements of the two or more arm members (6) and to apply an adaption rule to maintain the required flow below a predetermined maximum flow limit and to comply with the received arm member tip command (20) when generating the operating signals (24).

2. Working equipment (2) according to claim 1, wherein the equipment controller (18) is arranged to apply said adaption rule when generating the operating signals (24) to control the flow to the plurality of actuators (12) for moving each of the two or more arm members (6) by scaling, and prioritizing parameters in calculations performed when applying said

adaption rule, thereby resulting in smooth movements of said arm member tip (10).

3. Working equipment (2) according to claim 1 or 2, wherein said predetermined maximum flow limit is equal to or less than a maximal flow of hydraulic fluid discharged from said at least one hydraulic pump (14).

4. Working equipment (2) according to any of claims 1-3, wherein the adaption rule is a rule to maximise the velocity of the arm member tip (10), and the working equipment (2) is further arranged to apply said adaption rule to maximise the velocity when generating operating signals (24) to increase the required flow and comply with the received arm member tip command (20).

5. Working equipment (2) according to any of claims 1-4, wherein the adaption rule is:

- a rule to maximise the velocity of the arm member tip (10), or
- a rule to prioritise the accuracy of the position of the arm member tip (10), or
- a rule to prioritise the energy efficiency in the movement of the arm member tip (10).

6. Working equipment (2) according to any of claims 1-5, further comprising a remote control unit (26) configured to receive said arm member tip commands (20) of wanted arm member tip movements from an operator and to transmit the arm member tip commands (20) as arm member tip command signals (28) to the equipment controller (18), and wherein the remote control unit (26) further is configured to receive an adaption rule command from the operator by selecting one of said at least one adaption rule to be applied by the equipment controller (18).

7. Working equipment (2) according to any of claims 1-6, wherein the hydraulically movable arm arrangement (4) is a crane arm arrangement comprising one or many crane booms, telescopic booms, and crane boom extensions.

8. A vehicle (1) comprising a working equipment (2) according to any preceding claim.

9. A method of a working equipment (2), the working equipment comprises:

- a hydraulically movable arm arrangement (4) comprising two or more movable arm members (6) having an arm member configuration, and which are articulately connected to each other via arm member connections (8), such as arm member joints and telescopic boom extensions, and having associated connection functions, and an arm member tip (10) at a free end of the utmost of said two or more movable arm members (6);
- a plurality of actuators (12), arranged to be operated by hydraulic fluid discharged from at least one hydraulic pump (14) and further arranged to move the two or more arm members (6) of the movable arm arrangement (4) during a working assignment;
- a sensor system (16) comprising a plurality of sensors for sensing measures of various parameters of said movable arm arrangement (4), and
- an equipment controller (18), wherein the method comprises:

- receiving arm member tip commands (20), comprising characteristics of wanted movements of the arm member tip (10), such as a direction of movement for the arm member tip (10),
- receiving signals (22) from the sensor system (16), to determine and monitor current position of the arm member tip (10), one or many of relative positions of the two or more arm members (6), and position configurations and movement velocities of said arm member connections (8),
- controlling movements of the two or more arm members (6) in accordance with the received arm member tip commands (20), by generating and applying operating signals (24) controlling the flow and/or pressure of hydraulic fluid to the plurality of actuators (12),

characterized in that the method further comprises, monitoring, by said equipment controller (18), the required flow of hydraulic fluid from the at least one pump (14) for the movements of the two or more arm members (6) and applying an adaption rule to maintain the required flow below a predetermined maximum flow limit and to comply with the received arm member tip command (20) when generating the operating signals (24).

10. The method according to claim 9, comprising applying said adaption rule when generating the operating signals (24) to control the flow to the plurality of actuators (12) for moving each of the two or more arm members (6) by scaling, and prioritizing parameters in calculations performed when applying said adaption rule, thereby resulting in smooth movements of said arm member tip (10).

11. The method according to claim 9 or 10, wherein said predetermined maximum flow limit is equal to or less than a maximal flow of hydraulic fluid discharged from said at least one hydraulic pump (14).

12. The method according to any of claims 9-11, wherein the adaption rule is a rule to maximise the velocity of the arm member tip (10), and the method comprises applying said adaption rule to maximise the velocity when generating operating signals (24) to increase the required flow and comply with the received arm member tip command (20).

13. The method according to any of claims 9-12, wherein the adaption rule is:

- a rule to maximise the velocity of the arm member tip (10), or
- a rule to prioritise the accuracy of the position of the arm member tip (10), or
- a rule to prioritise the energy efficiency in the movement of the arm member tip (10).

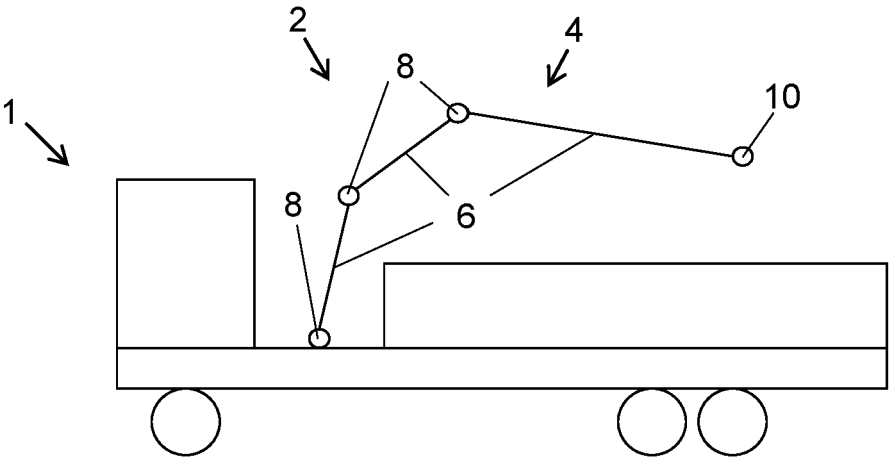


FIG. 1

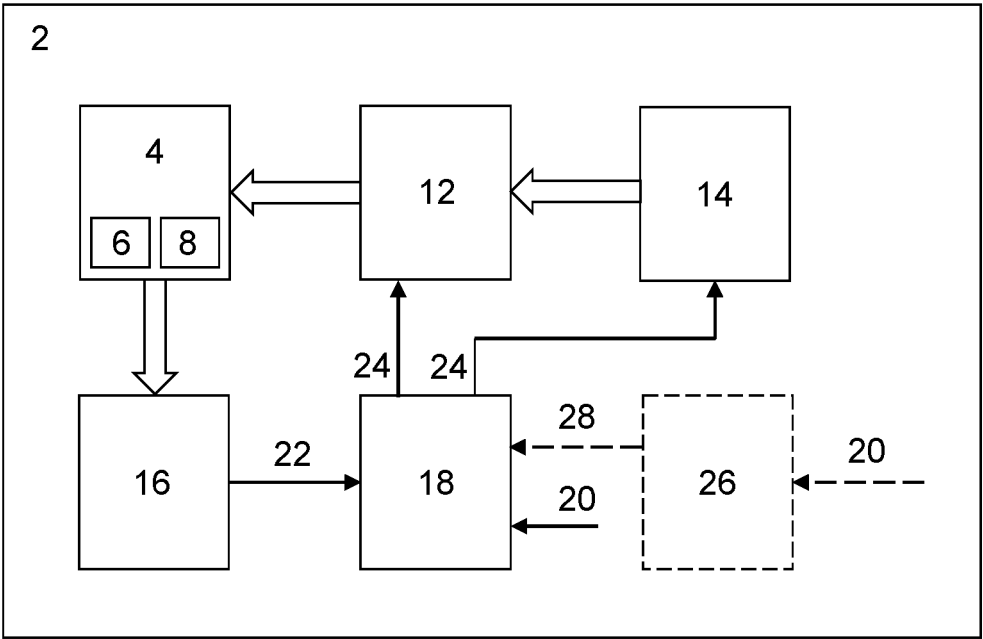


FIG. 2

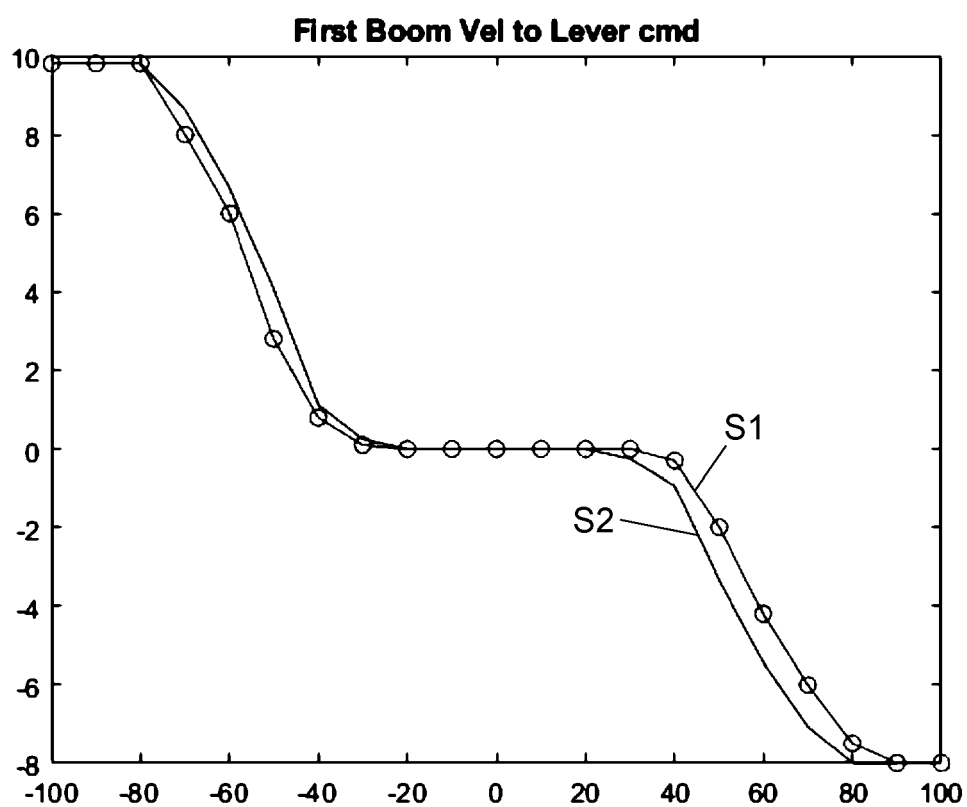


FIG. 3

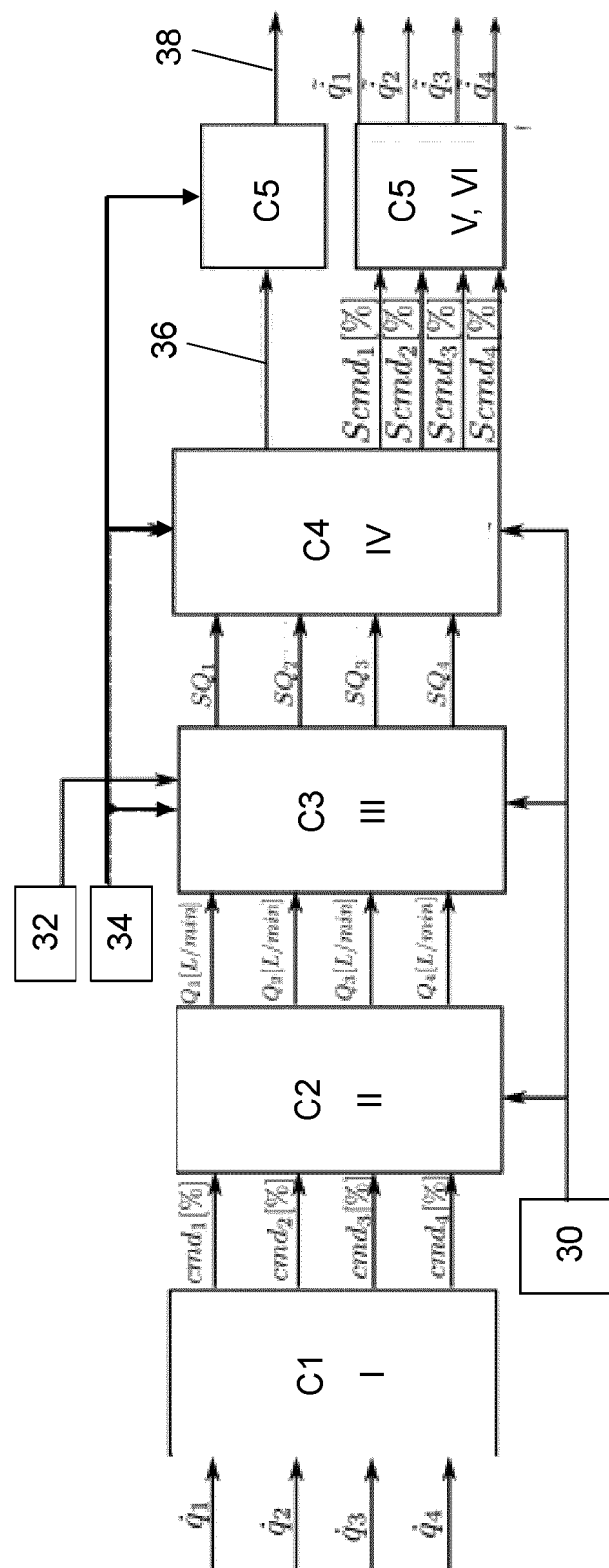


FIG. 4

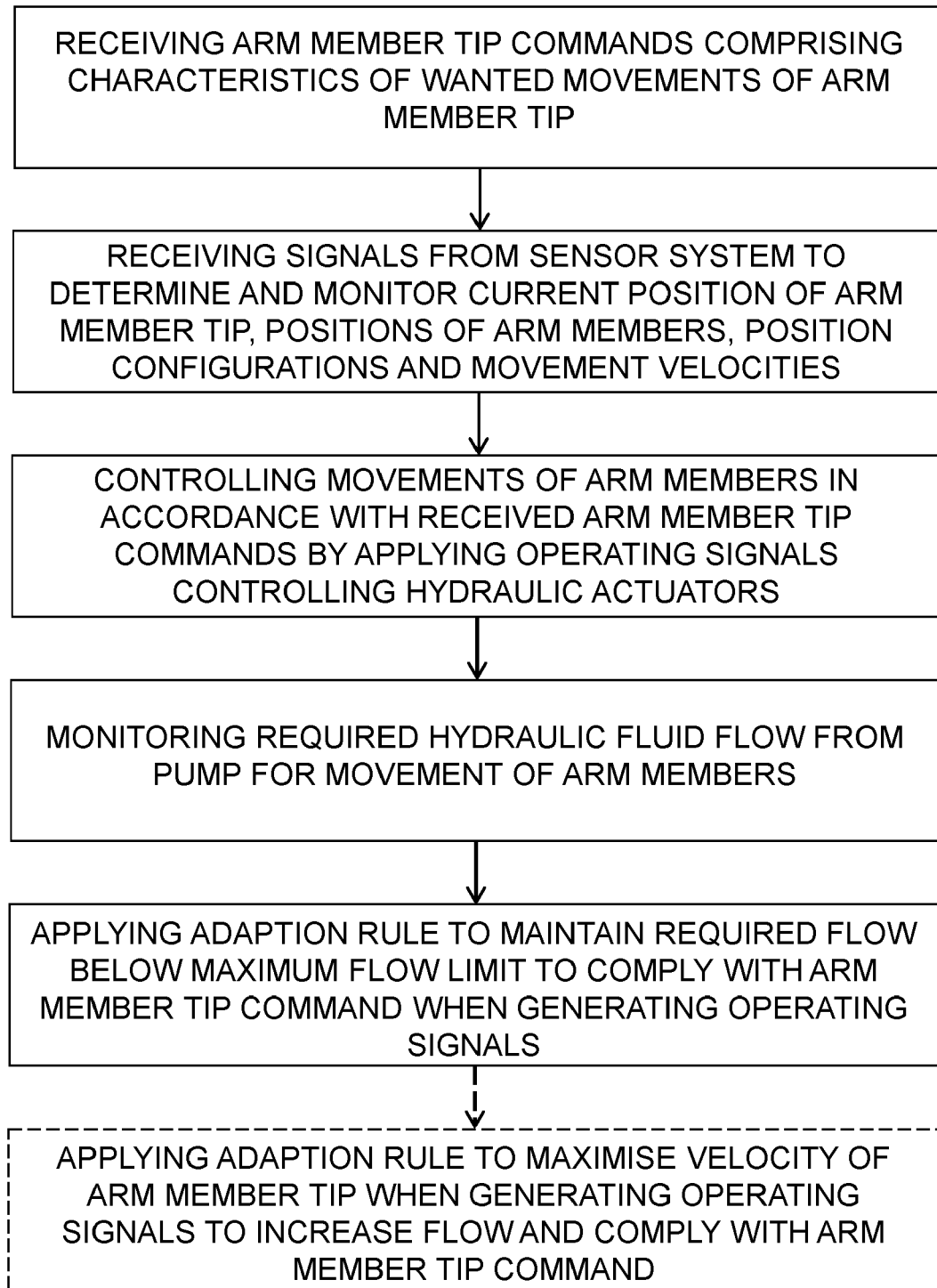


FIG. 5



EUROPEAN SEARCH REPORT

Application Number

EP 23 19 7085

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 498 973 B2 (CASE CORP [US]) 24 December 2002 (2002-12-24) * column 4, line 46 - column 11, line 9 * * figures *	1-6, 8-13	INV. B66C13/46 B66C13/48 B66F9/065 B66C23/08 B66C23/68 B66C13/20
X	EP 3 929 141 A1 (HIAB AB [SE]) 29 December 2021 (2021-12-29) * the whole document *	1-3, 5, 7-11, 13	
A	JP 4 308617 B2 (AICHI CORP KK) 5 August 2009 (2009-08-05) * abstract; figures *	1, 4, 5, 8, 9, 12, 13	
A	JP 4 107694 B2 (TADANO LTD) 25 June 2008 (2008-06-25) * abstract; figures *	1, 8, 9	
			TECHNICAL FIELDS SEARCHED (IPC)
			B66C E02F E04G B66F F15B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		28 February 2024	Özsoy, Sevda
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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			
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 19 7085

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
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28-02-2024

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6498973	B2	24-12-2002	NONE

EP 3929141	A1	29-12-2021	EP 3929141 A1
		US 2021404148 A1	29-12-2021
			30-12-2021

JP 4308617	B2	05-08-2009	JP 4308617 B2
		JP 2005104664 A	05-08-2009
			21-04-2005

JP 4107694	B2	25-06-2008	JP 4107694 B2
		JP H10226498 A	25-06-2008
			25-08-1998

25

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40

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20210231140 A1 [0004]
- EP 4086216 A1 [0005]
- US 6498973 B2 [0005]