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(54) **A METHOD OF CONTROLLING A CRANE, AND A CRANE**

(57) A crane (1) comprising a movable arm (2), and a tool (9) provided at an end of the movable arm (2). The crane (1) comprises a control system configured to a) detect a first condition in which the tool (9) is in a holding position and the movable arm (2) is in an unloaded condition in which it is not actively lifting an object held by said tool (9), b) registering a first point of time at which the first condition is obtained and counting a period of time (t) from the first point of time, and, c) when the counted period of time (t) exceeds a threshold value ($t_{threshold}$), activating a safe operation mode in the control system which prevents a first hydraulic device (3, 4, 5) from moving the movable arm (2), said safe operation mode being deactivatable by an actuation of a second hydraulic valve for controlling the holding position of the tool (9).

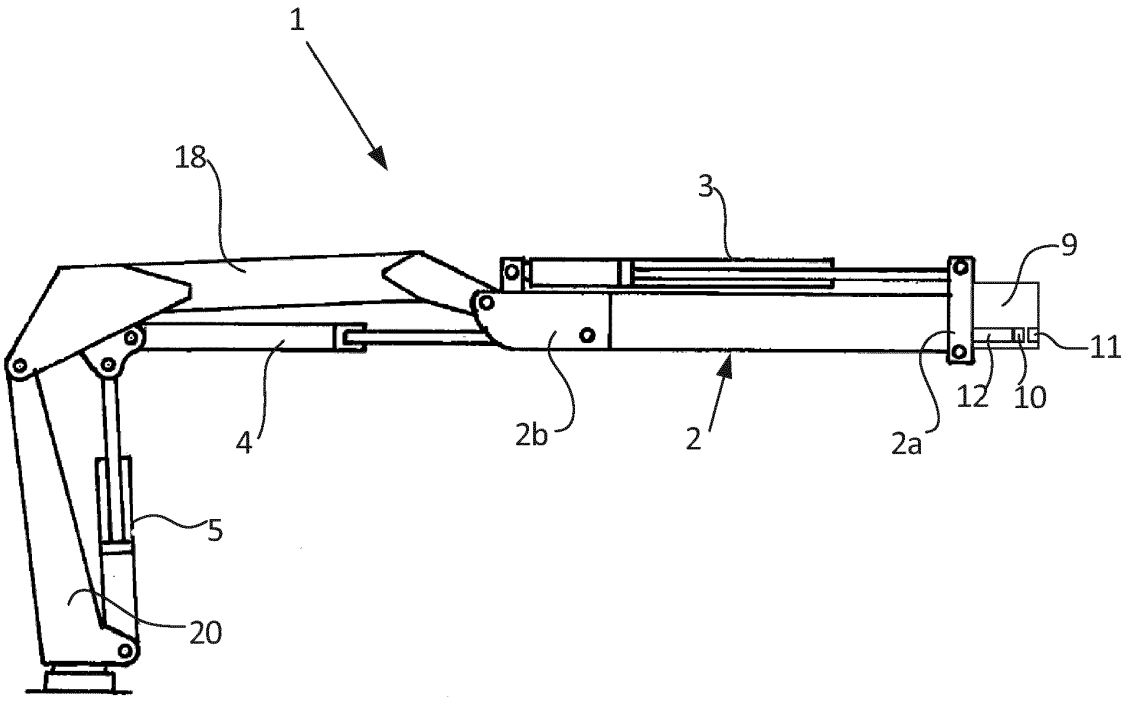

Fig. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method of controlling a crane, said crane comprising: a movable arm; at least one first hydraulic device configured to move the movable arm; a first hydraulic valve configured to control the operation of the at least one first hydraulic device; a tool provided at an end of the movable arm, said tool comprising a first part and a second part; a second hydraulic device configured to displace said first part in relation to said second part to a holding position in which the tool is configured to hold an object; a second hydraulic valve configured to control the operation of the second hydraulic device, and; a control system comprising a readable memory, a user interface configured to enable a user to control the movable arm and tool by receiving user commands, and a processor configured to control the first hydraulic device and the second hydraulic device by generating control signals to the first hydraulic valve and the second hydraulic valve in response to said received user commands.

[0002] The present invention also relates to such a crane.

BACKGROUND

[0003] Hydraulic cranes of the type defined hereinabove may be subjected to leakage of hydraulic liquid present in the hydraulic valve used for controlling the operation of the hydraulic device that controls the motion of the movable part of the tool that is responsible for holding an object. Such a leakage may imply that if the crane operator gives user commands for the tool to grip or hold an object and then waits a period of time before actually lifting the object with the crane, a situation where the tool no longer is in a gripping or holding position even though the crane operator may assume so, may arise. These situations may be a safety issue for the crane operator and may further lead to that the surrounding and objects handled by the crane are damaged.

[0004] This is a problem for cranes with hydraulically actuated crane tools, like for example hydraulic hooks and brick grabs. Often, this type of tools are designed so as to be locked in a holding position once the arm is actively lifting the object. This may be a mechanical locking of the tool caused by the own weight of the object being lifted. The locking in the holding position assumes that the tool is in fact in a holding position when the arm actively lifts the object. However, if leakage occurs during inactivity when no lifting is performed by the crane, the leakage may result in that the tool is not in the perfect holding position when lifting by means of the arm is started. The tool then runs the risk of dropping the object as the mechanical locking has not been achieved when initiating the lifting of the object.

[0005] It is an object of the present invention to present a method of controlling a crane, and a crane, that prevents unintentional dropping of an object caused by imperfect holding of the object due to leakage or other dysfunctionality in a valve that controls a hydraulic device that controls the operation of the tool.

SUMMARY

[0006] The object of the present invention is achieved by a method of controlling a crane, the crane comprising:

- a movable arm,
- at least one first hydraulic device configured to move the movable arm,
- a first hydraulic valve configured to control the operation of the at least one first hydraulic device,
- a tool provided at an end of the movable arm, the tool comprising a first part and a second part,
- a second hydraulic device configured to displace the first part in relation to the second part to a holding position in which the tool is configured to hold an object,
- a second hydraulic valve configured to control the operation the second hydraulic device,
- a control system comprising
  - a readable memory,
  - a user interface configured to enable a user to control the movable arm and tool by receiving user commands, and
  - a processor configured to control the first hydraulic device and the second hydraulic device by generating control signals to the first hydraulic valve and the second hydraulic valve in response to the received user commands, the method being **characterized in** that it comprises the steps of

    a) detecting a first condition in which the tool is in the holding position and the movable arm is in an unloaded condition in which it is not actively lifting an object held by the tool,

    b) registering a first point of time at which the first condition is obtained and counting a period of time from the first point of time, and

    c) when the counted period of time exceeds a threshold value (and said first condition is maintained), activating a safe operation mode in the control system which prevents the first hydraulic device from moving the movable arm, the safe operation mode being deactivatable by an actuation of the second hydraulic valve.

[0007] The deactivation of the safe operation mode may result from a direct actuation of the second hydraulic

valve in response to a crane operator command via the user interface. Alternatively, or as a supplement to the mentioned direct actuation, the deactivation of the safe operation mode may be an automatic actuation of the second hydraulic valve performed automatically by the control system itself as a response to a tentative by a user to move the movable arm when the safe operation mode is activated. The automatic actuation of the second hydraulic valve may be a predetermined actuation that results in that it is made sure that the first part is in a holding position before deactivating the safe mode. The actuation of the second hydraulic valve made in response to a user command may result in that it is made sure that the first part is in a holding position or that it is made sure that the first part is not in a holding position. If the crane operator gives a user command to move the first part into a position which is not a holding position then this indicates that the crane operator is aware of the fact that the tool is not holding the object and there is hence no risk that the object should be dropped during a movement of the movable arm. A tentative to move the movable arm includes any tentative to move a structural element which is movable via order from the user interface, wherein the structural element is connected the movable arm such that a motion thereof will also result in a motion of the movable arm. Such further structural element may typically be a boom which is part of the crane, to which boom the movable arm is connected. Also other structural elements, which are not hydraulically driven and the motion of which is controllable via the user interface, and the motion of which will induce a motion of the movable arm are prevented from being moved in the safe operation mode.

[0008] According to one embodiment the actuation of the second hydraulic valve is an actuation in response to a user command received via the user interface.

[0009] According to one embodiment the actuation of the second hydraulic valve is an actuation in response to a user command received via the user interface to apply the holding position.

[0010] According to one embodiment the control system is configured to be in an off-mode and an on-mode, wherein the method comprises the further steps of

- detecting a switch from the off-mode to the on-mode, and
- as a response to the switch being detected, activating the safe operation mode.

[0011] According to one embodiment the control system is configured to execute the steps of the method.

[0012] The object of the present invention is also achieved by a crane comprising:

- a movable arm,
- at least one first hydraulic device configured to move the movable arm,
- a first hydraulic valve configured to control the operation of the at least one first hydraulic device,
- a tool provided at an end of the movable arm, the tool comprising a first part and a second part,
- a second hydraulic device configured to displace the first part in relation to the second part to a holding position in which the tool is configured to hold an object,
- a second hydraulic valve configured to control the operation the second hydraulic device,
- a control system comprising

    - a readable memory,
    - a user interface configured to enable a user to control the movable arm and tool by receiving user commands, and
    - a processor configured to control the first hydraulic device and the second hydraulic device by generating control signals to the first hydraulic valve and to the second hydraulic valve in response to the received user commands, the crane being **characterized in** that the control system is configured to

        a) detect a first condition in which the tool is in the holding position and the movable arm is in an unloaded condition in which it is not actively lifting an object held by the tool,
        b) register a first point of time at which the first condition is obtained and counting a period of time from the first point of time, and
        c) when the counted period of time exceeds a threshold value (and said first condition is maintained), activate a safe operation mode which prevents the first hydraulic device from moving the movable arm, the safe operation mode being deactivatable by an actuation of the second hydraulic valve.

[0013] The deactivation of the safe operation mode may be a direct actuation of the second hydraulic valve through a user command received from a crane operator via the user interface. Alternatively, or as a supplement to the mentioned direct actuation, the control system may be configured to perform the deactivation of the safe operation mode by an automatic actuation of the second hydraulic valve performed as a response to a tentative by a user to move the movable arm when the safe operation mode is activated. A tentative to move the movable arm includes any tentative to move a structural element which is movable via an order from the user interface, wherein the structural element is connected to the movable arm such that a motion thereof will also result in a motion of the movable arm. Such further structural element may typically be a boom which is part of the crane, to which boom the movable arm is connected.

[0014] According to one embodiment the actuation of the second hydraulic valve is an actuation in response

to a user command received via the user interface. Thus, actuation of the second hydraulic valve can be simplified.

[0015] According to one embodiment the actuation of the second hydraulic valve is an actuation in response to a user command received via the user interface to apply the holding position.

[0016] According to one embodiment the control system is configured to be in an off-mode and an on-mode, wherein the control system is configured to

- detect a switch from the off-mode to the on-mode, and
- as a response to the switch being detected, activate the safe operation mode. Thus, in cases in which the control system has been in an off-mode for a time, and the time from the application of the off-mode to the switch to the on-mode has not been counted, the control system will automatically activate the safe operation mode.

[0017] According to one embodiment the off-mode is a mode in which power for actuation of the first and second hydraulic devices is turned off. According to one embodiment, the off-mode includes that the control system is disconnected from an electric power source.

[0018] According to one embodiment the crane comprises at least one pump configured to deliver pressurized fluid to the first hydraulic device and to the second hydraulic device, wherein, in the off-mode, the pump is inactive.

[0019] According to one embodiment the second hydraulic valve comprises a spool, a motion of which results in the displacement of the first part in relation to the second part to a holding position.

[0020] According to one embodiment the crane comprises at least one movable boom to which the arm is directly or indirectly connected, wherein, in the safe operation mode, movement of the boom, in particular a movement of the boom through an order via the user interface, is prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] In the following, embodiments of the invention are described with reference to the attached drawing, on which:

Fig. 1 is perspective view showing a crane according to an embodiment of the invention,
Fig. 2 is a schematic representation of a hydraulic system of the crane in Fig. 1,
Fig. 3 is a first side view showing a tool of the crane,
Fig. 4 is a second side view of the tool shown in Fig. 3, and
Fig. 5 is a flow chart of a method of controlling a crane according to the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0022] Fig. 1 shows an embodiment according to the invention of a crane 1 comprising a movable arm 2. The crane 1 may, for example, be mounted on a working machine, such as truck.

[0023] The crane 1 comprises a plurality of first hydraulic devices 3, 4, 5 configured to move the movable arm 2, and corresponding first hydraulic valves 6, 7, 8 (see fig. 2), which are configured to control the operation of the respective first hydraulic devices 3, 4, 5. The first hydraulic devices 3, 4, 5 each comprises a cylinder-piston arrangement.

[0024] At an end of the movable arm 2 there is provided a tool 9, which comprises a first part 10 and a second part 11. A second hydraulic device 12 is configured to displace the first part 10 in relation to the second part 11 to a holding position in which the tool 9 is configured to hold an object. The second hydraulic device 12 comprises a cylinder-piston arrangement. A second hydraulic valve 13 is configured to control the operation the second hydraulic device 12. The second hydraulic valve 13 is a directional valve, and comprises a spool. The flow of hydraulic liquid through the second hydraulic valve 13 depends on the position of the spool. A motion of the spool thus, results in the displacement of the first part in relation to the second part to or from the holding position. The first hydraulic valves 6, 7, 8 for controlling the motion of the movable arm 2 each has a corresponding design and functionality as the second hydraulic valve 13, but for the purpose of controlling the motion of the movable arm 2 by means of the first hydraulic devices 3, 4, 5.

[0025] Further, the crane 1 comprises a control system 14 comprising a readable 15 memory and a user interface 16. The user interface 16 is configured to enable a user to control the motions of the movable arm 2 and the tool 9 by receiving user commands via the user interface 16. The user commands may also be referred to as orders. In the embodiment shown, the user interface 16 is a handheld remote control device for controlling the motion of the arm 2 and the tool 9 by controlling the above-mentioned first hydraulic valves 6, 7, 8 and the second hydraulic valve 13. The user interface 16 may comprise a wired or a wireless control device or a combination of wired and wireless control devices. The user interface may allow for the crane to be controlled by a crane operator at the location of the crane or at a remote location with support from video images of the crane. The control system 9 further comprises a processor 17 configured to control the first hydraulic devices 3, 4, 5 and the second hydraulic device 12 by generating control signals to the first hydraulic valves 6, 7, 8 and to the second hydraulic valve 13 in response to the received user commands.

[0026] The control system 14 is configured to detect a first condition in which the tool 9 is in the holding position and the movable arm 2 is in an unloaded condition in which it is not actively lifting an object held by the tool 9.

The detection may be executed by means of suitable sensors, for example pressure sensors arranged in the first hydraulic devices. In another example, it may be determined by signals from a spool sensor monitoring the position of the spool in the hydraulic valve 13 whether the valve is actuated to set the tool 9 in a holding position. The loading condition of the movable arm 2 may for example be determined based on signals from pressure sensors arranged in the first hydraulic devices. The control system 14 may hence detect the first condition using a combination of signals received from suitable sensors.

[0027] The object may typically be resting on and be supported by ground in said first condition. Further, the control system 14 is configured to register a first point of time at which the first condition is obtained and counting a period of time from the first point of time. When the counted period of time exceeds a threshold value, and the first conditions is still maintained without any actuation of the second hydraulic device 12 during said time period, the control system is configured to activate a safe operation mode which prevents the first hydraulic devices 3, 4, 5 from moving the movable arm 2. The phrase "actively lifting the object" is here referring to the lifting of the object that is intended to be moved by the crane. A practical example may be a large package of building material that is to be moved from the load bed of a truck to a construction site where the building material is to be used. In order to be able to move the package with the crane, straps are often used to attach the package to a crane tool such as a hydraulic hook. Using this example the object to be moved would be the combination of the package of building material and the straps, so the crane would be actively lifting the object when the lifting action of the crane is applied to both the straps and the package of building material.

[0028] The safe operation mode is deactivatable by an actuation of the second hydraulic valve 13. In the presented exemplifying embodiment, the deactivation of the safe operation mode may be a direct actuation of the second hydraulic valve 13 through an actuation order by a user via the user interface 16. Alternatively, or as a supplement to the mentioned direct actuation, the deactivation of the safe operation mode may be an automatic actuation of the second hydraulic valve 13 performed by the control system 14 itself as a response to a tentative by a user to move the movable arm 2 when the safe operation mode is activated. The automatic actuation of the second hydraulic valve may hence make sure that the first part is in a holding position before the control system allows the movable arm 2 to be moved. A tentative to move the movable arm 2 includes any tentative to move a structural element which is movable via order from the user interface 16, wherein the structural element is connected the movable arm 2 such that a motion thereof will also result in a motion of the movable arm 2. Such further structural element may typically be a boom 18 which is part of the crane, to which boom 18 the movable arm is connected.

[0029] In the shown embodiment, the order to the second hydraulic valve 13 which triggers a deactivation of the safe operation mode is an order to apply the holding position, either by the user via the user interface 16 or automatically by the control system 14 itself. The order to the second hydraulic valve 13 which triggers a deactivation of the safe operation mode may be an order to apply the holding position or a release position for the tool 9 in the case that the order is received from a crane operator via the user interface 16. In the case of the automatic actuation the control system 14 actuates the second hydraulic valve to set the tool in a holding position.

[0030] In the embodiment described here, the control system 14 is configured to be in an off-mode and an on-mode. The control system 14 is configured to detect a switch from the off-mode to the on-mode, and, as a response to the switch being detected, activate the safe operation mode. The off-mode is a mode in which power for actuation of the first hydraulic devices 3, 4, 5 and the second hydraulic devices 12 is turned off and the control system 14 is disconnected from an electric power source (not shown). The crane 1 comprises at least one pump 19 configured to deliver pressurized fluid to the first hydraulic devices 3, 4, 5 and to the second hydraulic device 12. In the off-mode, the pump 19 is inactive.

[0031] In the illustrated embodiment, the hydraulic crane 1 comprises further structural elements, which are connected to the movable arm 2 and provided with hydraulic devices for moving those further structural elements. The control system 9 is configured to enable a user to move said further structural elements via orders received by the user interface. Any motion of such a further structural element, which results in a motion of the movable arm 2, is regarded as a motion of the movable arm 2. The first hydraulic devices 3, 4, 5 for moving the movable arm thus includes a hydraulic device 5 for moving the boom 18 in relation to a column 20, which is also part of the crane 1. The arm 2 itself is telescopic and comprises a first part 2a and a second part 2b. One of the first hydraulic devices 3 is configured to telescopically displace said first part 2a in relation to the second part 2b. Another first hydraulic device 4 is configured to pivot the arm 2 in relation to the boom 18.

[0032] Also other possible structural elements, which are not hydraulically driven and the motion of which is controllable via the user interface 16, and the motion of which will induce a motion of the movable arm 2 are prevented from being moved in the safe operation mode.

[0033] Fig. 5 is a flow chart of a method of controlling a crane 1 illustrated in Fig. 1. The method comprises the steps of

- detecting (S1) a first condition in which the tool 9 is in the holding position and the movable arm 2 is in an unloaded condition in which it is not actively lifting an object held by the tool 9,
- registering (S2) a first point of time at which the first condition is obtained and counting a period of time

t from the first point of time, and

- when the counted period of time t exceeds a threshold value $t_{threshold}$, activating (S3) a safe operation mode in the control system which prevents the first hydraulic device from moving the movable arm 2, the safe operation mode being deactivatable by an actuation of the second hydraulic valve 13, automatic or manual.

[0034] The control system is configured to be in an off-mode and an on-mode, and step S3 also comprises

- detecting a switch from the off-mode to the on-mode, and
- as a response to the switch being detected, activating the safe operation mode

[0035] When the safe operation mode is deactivated, the counted period of time t is further reset to zero. After deactivating the safe operation mode, the counting will hence start from zero when a condition in which the tool 9 is in the holding position and the movable arm 2 is in an unloaded condition, once again is detected.

[0036] If the time counter has been inactive due to the control system 14 having been in the off-mode, the control system will thus ensure that the safe operation mode is active upon detection that a switch to the on-mode has been performed, irrespectively of the fact that the counted period of time may be less than said threshold value.

Claims

1. A method of controlling a crane (1), said crane (1) comprising:

   - a movable arm (2),
   - at least one first hydraulic device (3, 4, 5) configured to move the movable arm (2),
   - a first hydraulic valve (6, 7, 8) configured to control the operation of the at least one first hydraulic device (3, 4, 5),
   - a tool (9) provided at an end of the movable arm (2), said tool (4) comprising a first part (10) and a second part (11),
   - a second hydraulic device (12) configured to displace said first part (10) in relation to said second part (11) to a holding position in which the tool (9) is configured to hold an object,
   - a second hydraulic valve (13) configured to control the operation the second hydraulic device (12),
   - a control system (14) comprising

     - a readable memory (15),
     - a user interface (16) configured to enable a user to control the movable arm (2) and the tool (9) by receiving user commands, and
     - a processor (17) configured to control the first hydraulic device (3, 4, 5) and the second hydraulic device (12) by generating control signals to the first hydraulic valve (6, 7, 8) and to the second hydraulic valve (13) in response to said received user commands, said method being **characterized in that** it comprises the steps of

       a) detecting a first condition in which the tool (9) is in said holding position and the movable arm (2) is in an unloaded condition in which it is not actively lifting an object held by said tool (9),
       b) registering a first point of time at which the first condition is obtained and counting a period of time (t) from the first point of time, and
       c) when the counted period of time (t) exceeds a threshold value ($t_{threshold}$), activating a safe operation mode in the control system (14) which prevents the first hydraulic device (3, 4, 5) from moving the movable arm (2), said safe operation mode being deactivatable by an actuation of said second hydraulic valve (13).

2. A method according to claim 1, **characterized in that** said actuation of said second hydraulic valve (13) is an actuation in response to a user command received via the user interface (16).

3. A method according to claim 2, **characterized in that** said actuation of the second hydraulic valve (13) is an actuation in response to a user command received via the user interface (16) to apply said holding position.

4. A method according to any one of claims 1-3, **characterized in that** the control system (14) is configured to be in an off-mode and an on-mode, and that the method comprises the further steps of

   - detecting a switch from said off-mode to said on-mode, and
   - as a response to said switch being detected, activating said safe operation mode.

5. A method according to any one of claims 1-3, **characterized in that** the control system (14) is configured to execute the steps of the method.

6. A crane (1) comprising:

   - a movable arm (2),

- at least one first hydraulic device (3, 4, 5) configured to move the movable arm (2),
- a first hydraulic valve (6, 7, 8) configured to control the operation of the at least one first hydraulic device (3, 4, 5),
- a tool (9) provided at an end of the movable arm (2), said tool (9) comprising a first part (10) and a second part (11),
- a second hydraulic device (12) configured to displace said first part (10) in relation to said second part (11) to a holding position in which the tool (9) is configured to hold an object,
- a second hydraulic valve (13) configured to control the operation the second hydraulic device (12),
- a control system (14) comprising

    - a readable memory (15),
    - a user interface (16) configured to enable a user to control the movable arm (2) and the tool (9) by receiving user commands, and
    - a processor (17) configured to control the first hydraulic device (3, 4, 5) and the second hydraulic device (12) by generating control signals to the first hydraulic valve (6, 7, 8) and to the second hydraulic valve (13) in response to said received user commands, said crane being **characterized in that** the control system (14) is configured to

        a) detect a first condition in which the tool (9) is in said holding position and the movable arm (2) is in an unloaded condition in which it is not actively lifting an object held by said tool (9),
        b) register a first point of time at which the first condition is obtained and counting a period of time (t) from the first point of time, and
        c) when the counted period of time (t) exceeds a threshold value ($t_{threshold}$), activate a safe operation mode which prevents the first hydraulic device (3, 4, 5) from moving the movable arm (2), said safe operation mode being deactivatable by an actuation of said second hydraulic valve (13).

7. A crane (1) according to claim 6, **characterized in that** said actuation of the second hydraulic valve (13) is an actuation in response to a user command received via the user interface (16).

8. A crane (1) according to claim 7, **characterized in that** said actuation of the second hydraulic valve (13) is an actuation in response to a user command received via the user interface (16) to apply said holding position.

9. A crane (1) according to any one of claims 6-8, **characterized in that** the control system (14) is configured to be in an off-mode and an on-mode, and that the control system (14) is configured to

- detect a switch from said off-mode to said on-mode, and
- as a response to said switch being detected, activate said safe operation mode.

10. A crane (1) according to claim 9, **characterized in that** said off-mode is a mode in which power for actuation of the first and second hydraulic devices (3, 4, 5, 12) is turned off and the control system (14) is disconnected from an electric power source.

11. A crane (1) according to claim 9 or 10, **characterized in that** it comprises at least one pump (19) configured to deliver pressurized fluid to the first hydraulic device (3, 4, 5) and to the second hydraulic device (12), and that, in said off-mode, said pump is inactive.

12. A crane (1) according to any one of claims 6-11, **characterized in that** the second hydraulic valve (13) is a directional valve.

13. A crane (1) according to any one of claims 6-12, **characterized in that** the second hydraulic valve (13) comprises a spool, a motion of which results in said displacement of said first part (10) in relation to said second part (11) to the holding position.

14. A crane (1) according to any one of claims 6-13, **characterized in that** the crane (1) comprises at least one movable boom (18) to which the arm (2) is directly or indirectly connected and that, in said safe operation mode, movement of said boom (18) is prevented.

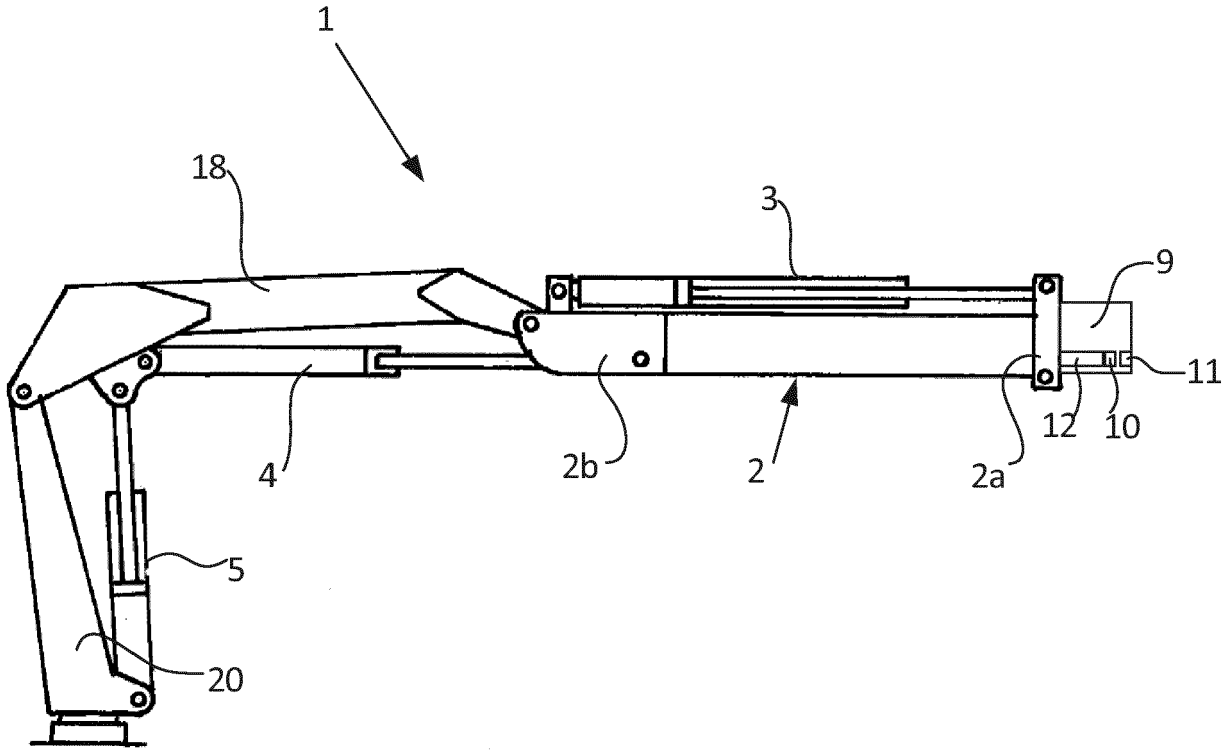

Fig. 1

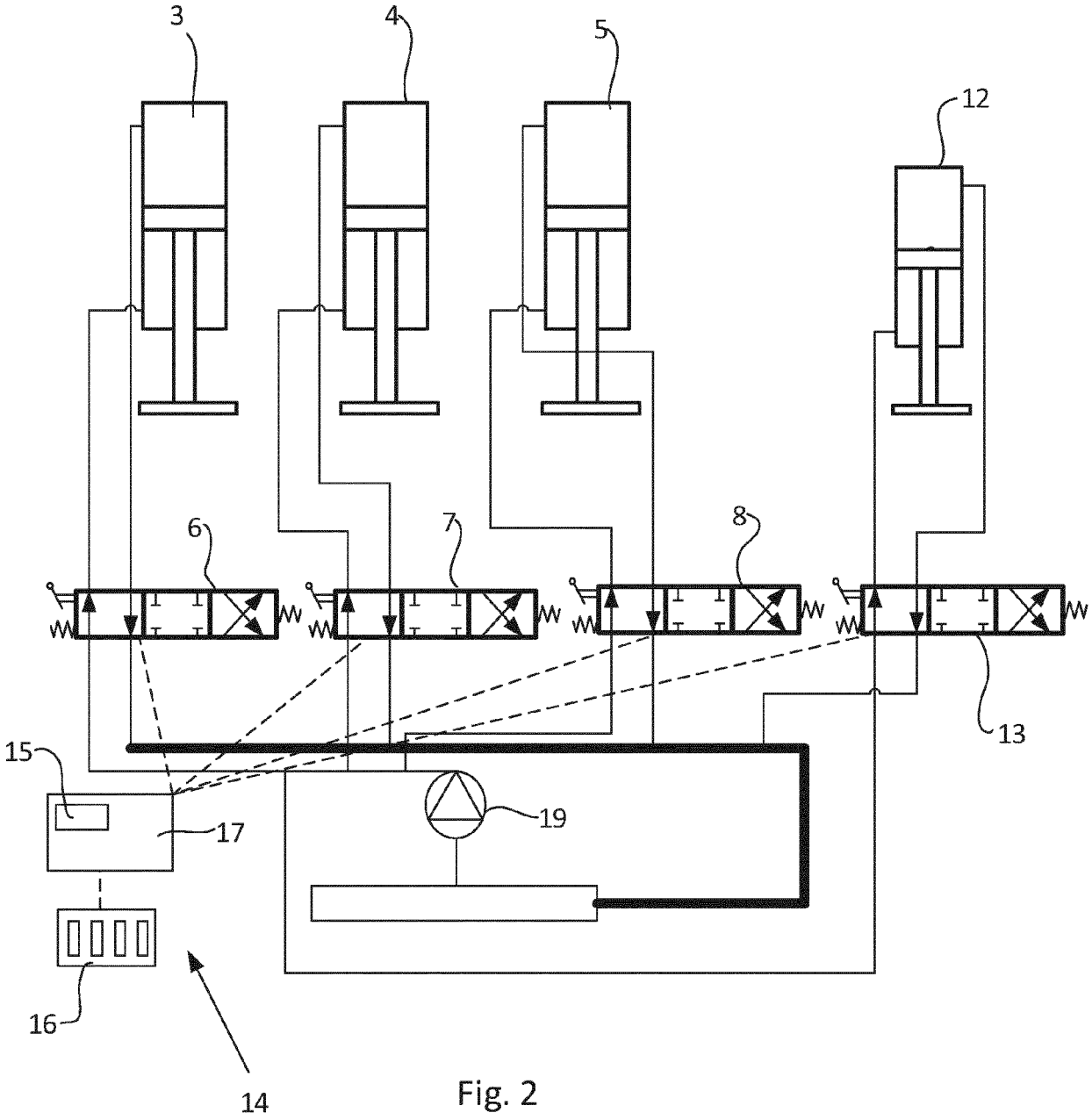

Fig. 2

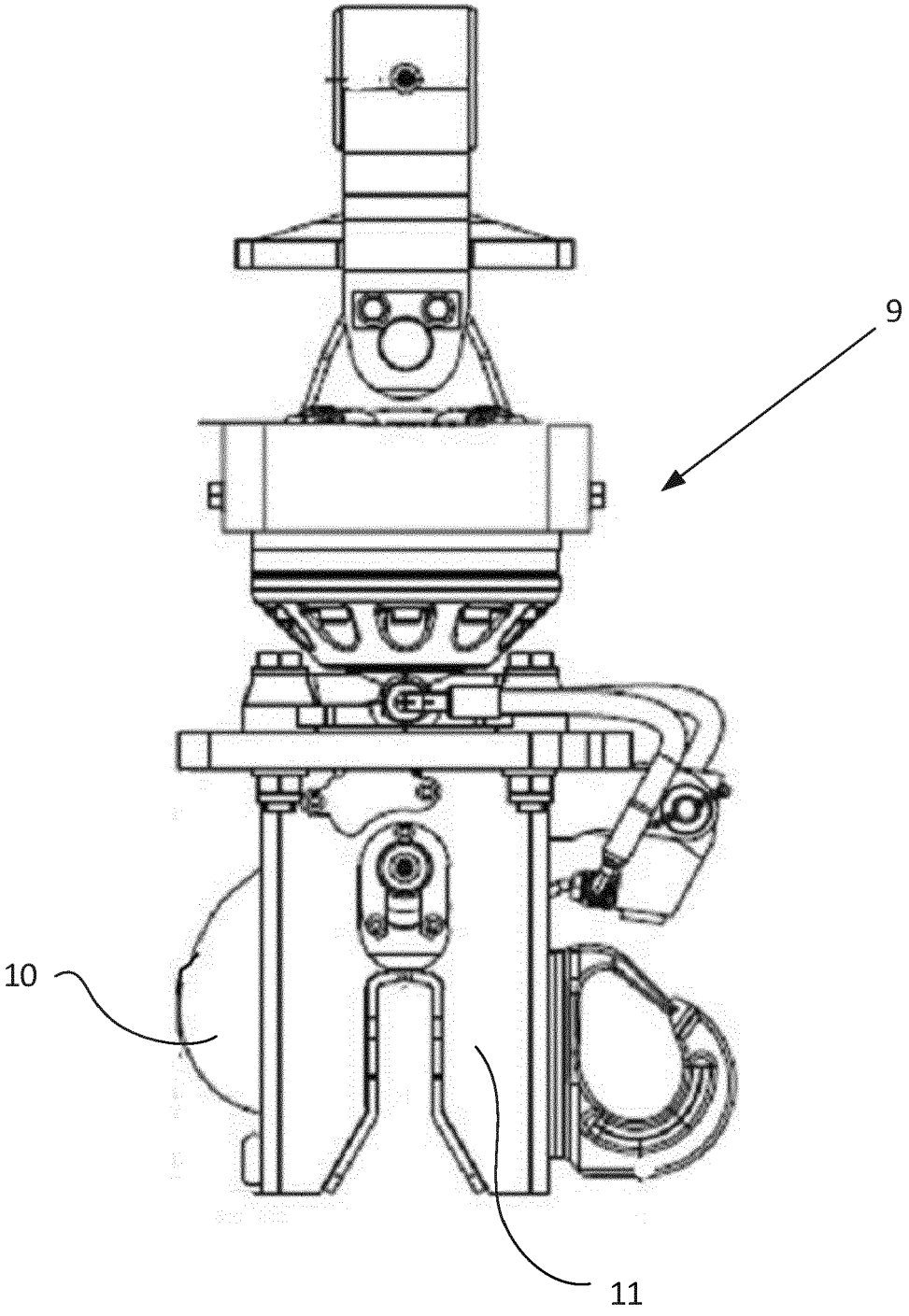

Fig. 3

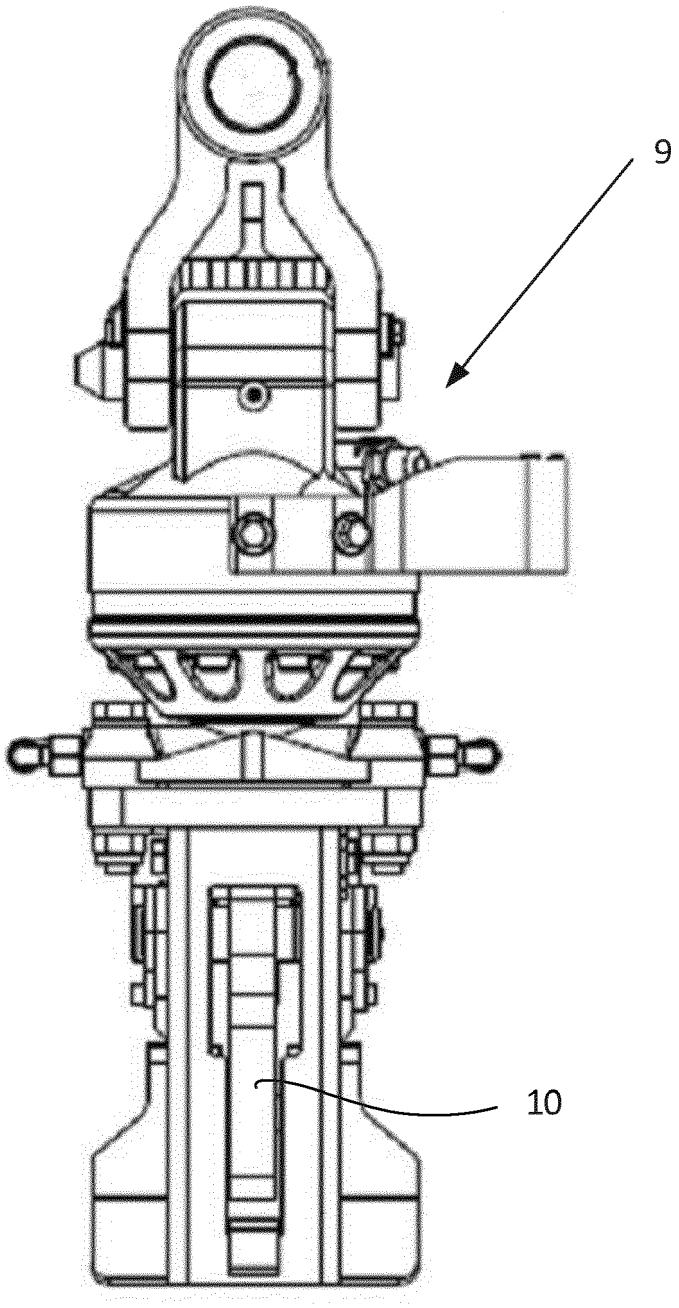

Fig. 4

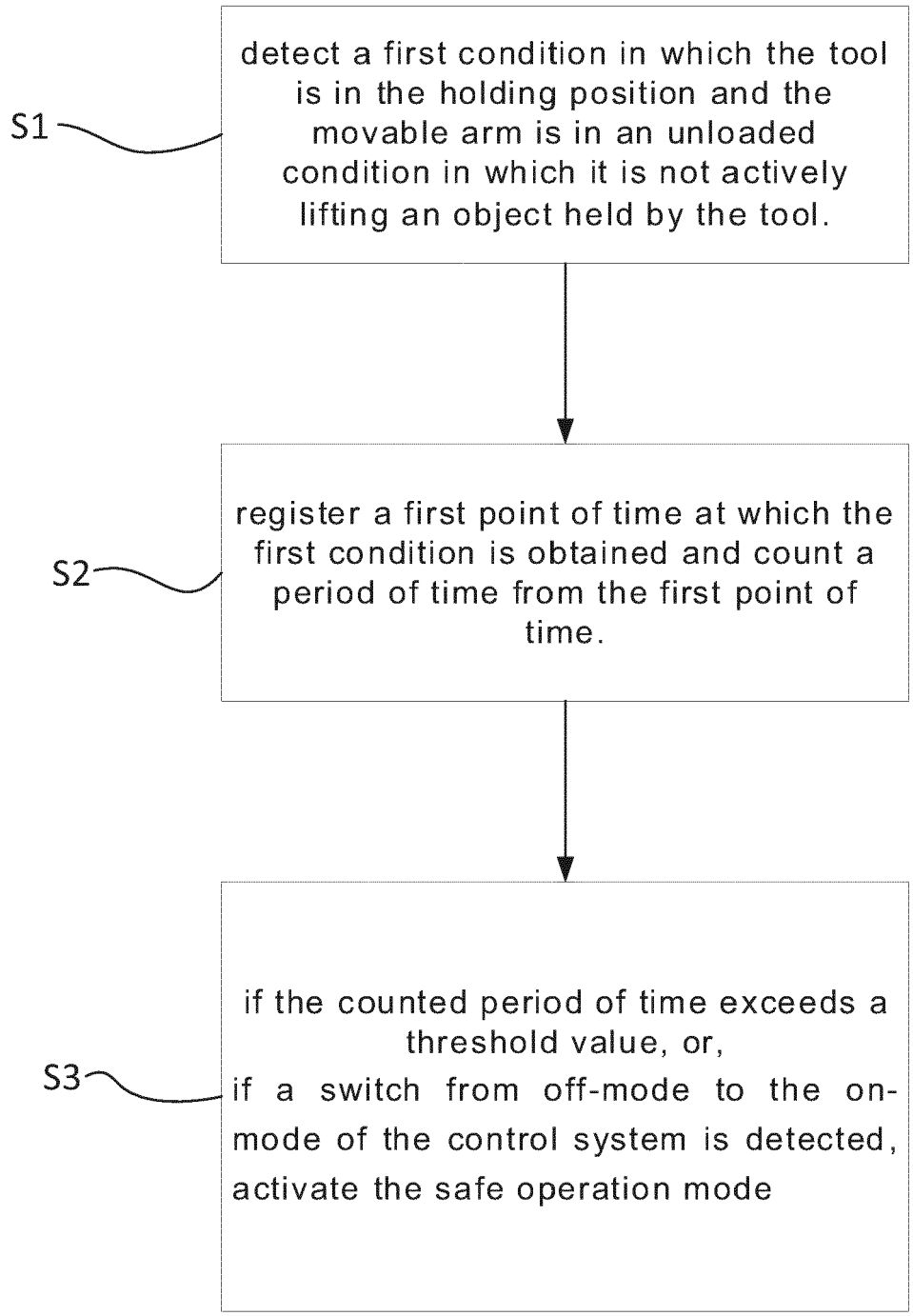
S1
detect a first condition in which the tool is in the holding position and the movable arm is in an unloaded condition in which it is not actively lifting an object held by the tool.
S2
register a first point of time at which the first condition is obtained and count a period of time from the first point of time.
S3
if the counted period of time exceeds a threshold value, or,
if a switch from off-mode to the on-mode of the control system is detected,
activate the safe operation mode

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 5232

DOCUMENTS CONSIDERED TO BE RELEVANT

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CATEGORY OF CITED DOCUMENTS

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