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(54) A CONTROLLER AND A METHOD FOR CONTROLLING THE FLOW RATE THROUGH A HYDRAULIC VALVE

(57) An arrangement for controlling the flow rate through a hydraulic valve, the arrangement comprising a control device having a first range of positions for providing a first range of flow rates through the hydraulic valve, a second range of positions for providing a second range of flow rates through the hydraulic valve, and a neutral position for providing substantially no flow through the hydraulic valve, wherein the relationship between the first range of flow rates through the hydraulic valve and the first range of positions of the control device is substantially linear having a first ratio and the relationship between the second range of flow rates through the hydraulic valve and the second range of positions of the control device is substantially linear having a second ratio.

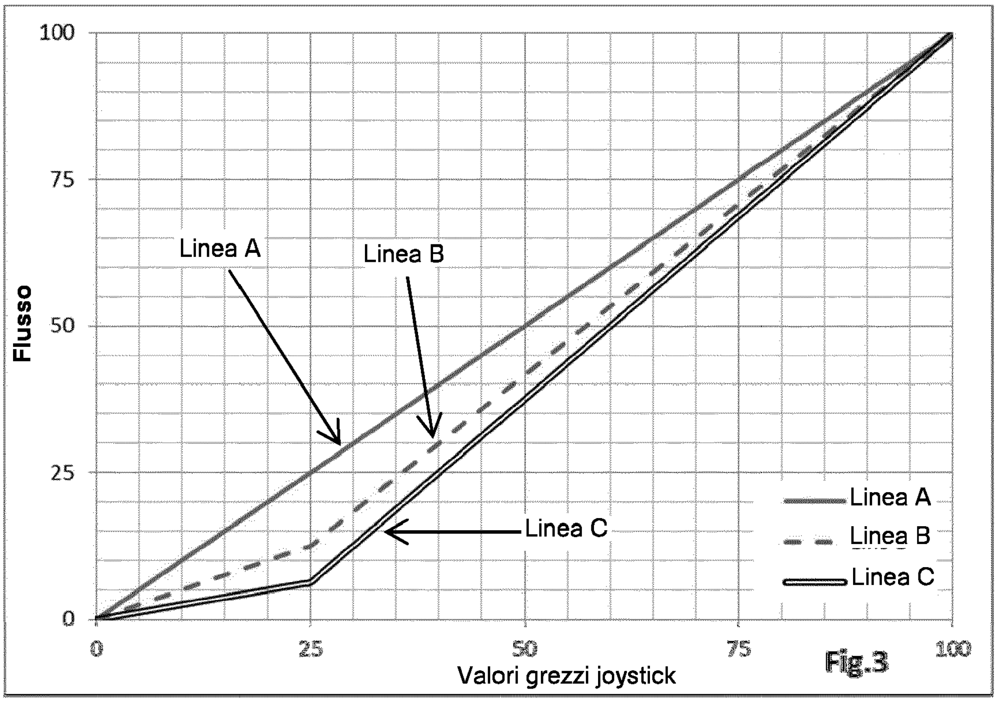

Fig.3

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Description

[0001] The present invention relates to a controller and a method for controlling the flow rate through a hydraulic valve, in particular controlling the flow rate through a hydraulic valve for work vehicles.

[0002] Hydraulic valves provide auxiliary hydraulic flows to implements that are coupled to vehicles for performing various tasks. Implements may be coupled at the front, e.g. front loaders, or at the rear. Typically, such a vehicle will have several such valves, commonly varying between two and eight. These valves are controlled in an operator station typically in the cab of the vehicle, most commonly by manipulating a lever or knob that provides a signal proportional to the movement of the lever or knob and indicates a desired flow rate to or from an auxiliary hydraulic valve.

[0003] The hydraulic valves are typically connected to a manifold or manifolds to which hydraulic actuators are mounted. These hydraulic actuators include such things as hydraulic motors and cylinders. By varying the position of the lever or knob, the operator can vary the flow direction and flow rate to the manifold, and consequently to the hydraulic actuators located on the implement.

[0004] Another common user input located at the operator station is a flow rate control. The flow rate control is typically a small dial or knob that is set by the operator and indicates a maximum flow rate through the valve. Thus, by rotating the flow rate control, the operator can limit the operating range of the lever or knob from a flow rate of zero to a positive or negative flow rate.

[0005] Typically, the flow rate controls can provide the same maximum flow rates in both extend and retract modes of operation. In other words, when the control lever is moved to one extreme limit, for a given flow rate control setting it will provide a maximum flow rate through the hydraulic valve. Similarly, when the control lever is moved to the opposite extreme limit, for a given flow rate control setting it will provide a maximum flow rate through the hydraulic valve in the reverse direction through the valve.

[0006] For example, if the flow rate control is moved to a position that reduces the maximum flow by half, moving the control lever to one extreme will cause half the maximum flow rate to flow through the hydraulic valve. If the control lever is moved to the other extreme position, half the maximum flow rate to flow through the hydraulic valve in the opposite direction.

[0007] Alternatively there are can be two separate maximum flow rate controls for a hydraulic valve. One in the extend mode, the other in the retract mode. In this situation, the operator may set a 80% maximum flow rate in extend mode and 20% maximum flow rate in retract mode.

[0008] However, for a lot of operators this level of flow control is insufficient. As the relationship between the movement of the control lever and the flow rate through the hydraulic valve is linear, it can be difficult for the operator to precisely control the operation of an implement attached to the vehicle when low flow rates through the hydraulic valve are required, while also allowing rapid operation of the implement, which requires high flow rates through the hydraulic valves. In particular, an operator typically requires good control of flow rates around the central position of the control lever.

[0009] It is desirable to improve this situation.

[0010] In accordance with an aspect of the present invention there is provided a controller and method according to the accompanying claims.

[0011] The invention as claimed provides the advantage of allowing different hydraulic valve flow rate characteristics to be assigned to different ranges of movement of a control device, in other words, the relationship between valve flow rates and movement of a control device is non-linear. This allows one range of positions of the control device to provide precise operator control with another range of positions for the control device allowing the operator to provide rapid operation of an implement.

[0012] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates a work vehicle, shown as a tractor, having a hydraulic valve flow rate controller according to an embodiment of the present invention;

Figure 2 illustrates a joystick according to an embodiment of the present invention;

Figure 3 illustrates a first flow rate ratio according to an embodiment of the present invention;

Figure 4 illustrates a second flow rate ratio according to an embodiment of the present invention.

Figure 1 illustrates a vehicle 10 having an engine 12 drivingly engaged to a transmission 14 by a drive shaft 16, which are mounted on a chassis 35. The transmission 14 is in turn coupled through drive shafts 18 and 20 to front differential 22 and rear differential 24. Front wheels 26 are coupled to and driven by differential 22 and rear wheels 28 are coupled to and driven by differential 24. A hydraulic pump 30 is coupled to and driven by engine 12. The pump

30 provides hydraulic fluid to auxiliary valves 40.

[0013] Inside the cab 32 is an operator station 33 that includes a control device in the form of a control lever 34, a flow rate control 36 and an electronic display. These controls are coupled to a controller 38. The controller 38 drives the display to provide the operator with indicia indicating each of the auxiliary hydraulic valves 40, selectable directions of flow for each valve and selectable valve offsets.

[0014] The control lever 34 is used by the operator to control the amount of fluid flow through an auxiliary valve, while the flow rate control 36 is used by the operator to select the maximum possible flow rate through an auxiliary valve.

[0015] Controller 38 is arranged to receive operator commands from the flow rate control 36 and control lever 34 and converts these commands into valve signals which are applied to auxiliary hydraulic control valves 40. Valves 40 regulate the flow of fluid between pump 30 and auxiliary valve manifold 42, front- or mid-mounted or located at the rear of the vehicle. Manifold 42 typically includes quick-connect couplings that provide bi-directional flow to implements (not shown) that have mating hydraulic connectors.

[0016] The control lever 34 is a manually actuated operator input device, typically including either a lever, joystick or a knob, which generates a signal indicative of the lever position, which in turn is used to determine fluid flow through an auxiliary valve, as described below. The control lever 34 may include a potentiometer or a shaft encoder to provide a computer readable signal to controller 38. A preferred implementation of the control level 34 is illustrated in Figure 2.

[0017] The flow rate control 36 is a manually actuated operator input device, typically including a knob, which generates a signal indicative of the position of the device. The flow rate control 36 may include a potentiometer or a shaft encoder to provide a computer readable signal to the controller 38. The flow rate control 36 defines the selected maximum flow rate, being a parameter that is a portion of the absolute maximum flow rate through an auxiliary valve. This parameter may also be input through a HMI to the controller 38 instead of using flow rate control 36. The maximum flow rate can be indicated as an absolute value (l/h) or a portion of the absolute maximum flow rate of the circuit (%).

[0018] Preferably, a load sensing and control circuit 44 is fluidly coupled to valves 40 and pump 30. The control circuit 44 receives signals from each of the auxiliary hydraulic valves (40) and transmits a signal indicative of the hydraulic load on the valves to pump 30. Pump 30, in turn, varies its specific hydraulic output (i.e. the volume of hydraulic fluid per single revolution or cycle of pump 30) in accordance with the load signal that it receives.

[0019] Controller 38 is electrically coupled to valves 40 and generates a valve signal indicative of the degree of desired valve opening for each of the valves, based on the respective positions of the control lever 34 and flow rate control 36.

[0020] It should be understood that the system is not limited to any particular number of auxiliary hydraulic control valves.

[0021] Controller 38 transmits a signal to valve actuators. The valve actuators typically include an electrical coil responsive to the current transmitted from controller 38 and open the valve proportional to the current flowing through the actuators. In this manner, controller 38 can selectively apply individual signals to each of the valves 40 causing them to separately and independently open or close.

[0022] Preferably, each valve is connected to quick connect couplings located at manifolds 42. There are typically two hydraulic lines extending between each valve and the manifold. Preferably, on the hydraulic lines extending between the valves and the couplings, bi-directional flow is provided in each hydraulic line.

[0023] Preferably, each of the hydraulic valves 40 are also connected to a hydraulic reservoir or tank for receiving fluid returned from the implement (not shown).

[0024] In one embodiment, one control lever 34 and one flow rate control 36 is provided for each of the auxiliary hydraulic valves in the vehicle. In operation, the operator moves a lever 34 to indicate a desired flow rate to one of valves 40. This signal, typically an electrical signal, is received by the controller 38 which uses this signal to generate a signal to the appropriate valve actuator for controlling the fluid flow through the appropriate valve. In this manner, electronic controller 38 responds to operator commands and generates an appropriate valve signal.

[0025] However, in a preferred embodiment, for a two valve system the control lever 34 takes the form of a joystick that is used for providing operator control of one valve via movement of the joystick along an Y axis and for providing operator control of the second valve via movement of the joystick along an X axis, thereby allowing a single joystick to be used to control the operation of two valves, as illustrated in Figure 2.

[0026] As stated above, each valve 40 is bi-directional, where the direction of fluid flow determines whether the implement being operated is moving in a "retract" direction or an "extend" direction. When the lever 34 (i.e. the joystick) is in a 'neutral' position, for example a central position between the extreme X axis and Y axis positions, the controller 38 is arranged to prevent fluid flow through the valves 40. Further, is it possible to disable all the joystick commands by putting the joystick in its middle position (i.e. in the 'neutral' position). As such, the controller 38 defines a first range of flow rates for one direction of the joystick 34, a central position for providing substantially no flow through a valve 40, and another range of positions providing a second range of flow rates in the opposite direction when the joystick 34 is operated in the opposite direction.

[0027] The joystick 34 has three switches 20, 21, 22 for controlling the operation of the auxiliary valves 40, however as these switches 20, 21, 22 are not relevant to the present invention they will not be described in any further detail.

[0028] During normal operation, for a given flow direction, the controller 38 is arranged to control the flow rate through a valve 40 so that the flow rate is proportional to the movement of the joystick 34, thereby providing a linear relationship between flow rate and joystick movement. This linear relationship can only be influenced by the maximum flow parameter, adjustable by the flow rate control 36 or directly through a HMI to controller 38.

[0029] Further, however, the controller 38 may also be placed in a non-linear mode of operation where the relationship between the flow rate through a valve 40 and the movement of the joystick 34 is non-linear, as described in detail below. By providing a non-linear relationship between the valve flow rate and joystick position allows the operator greater control of valve flow rates around the central position of the joystick 34.

[0030] During operation, the controller 38 periodically polls the flow rate control 36 and the joystick 34 to determine whether the operator has moved either device. When the operator moves either device 34 or 36, the controller 38 senses the change virtually instantly, recalculates the appropriate valve signal and applies that signal to the corresponding valve.

[0031] When the controller 38 receives the respective control signals from the joystick 34 and the flow rate control 36 the controller 38 converts these signals into a numeric value dependent upon whether the system is operating in normal operation mode or non-linear operation mode.

[0032] Although the range of values produced by the controller 38 when the joystick is moved through its entire range is arbitrary, for the purposes of the present embodiment the joystick values varies from -100 to +100 when the joystick is moved from the maximum retract flow rate position (i.e. one mechanical lever limit) to the maximum extend flow rate position (the other mechanical lever limit) in both axis of movement. An intermediate or central position, generally midway between these two limits, would provide a value of zero and would be indicative of a zero flow rate, neither extend nor retract (i.e. in the neutral position).

[0033] Similarly, although the range of values produced by the controller 38 when the flow rate control 36 is moved through its entire range is arbitrary, for the purposes of the present embodiment the flow rate control value can vary from 0 (indicative of a zero flow rate) to +100 (indicative of the maximum desired flow rate through the valve) when the flow rate control 36 is moved from an extreme counter clockwise position to an extreme clockwise position. An intermediate position generally midway between these two limits would provide a value of 50.

[0034] For the purposes of one embodiment, the process for an operator to enter the non-linear mode of operation requires a non-linear mode switch 23 that is mounted on the joystick base 24 to be activated and the position of the joystick needs to be within a predetermined angle, for example thirty degrees, of the joysticks central position. If the joystick is moved to an angle greater than the predetermined angle and the non-linear mode switch is deactivated the controller 38 is arranged to exit the non-linear operation mode and to operate in normal operation mode. However, any suitable means for selecting the non-linear mode of operation may be used.

[0035] In a further, preferred embodiment, the non-linear mode of operation is the default and only mode of operation. In this situation the selection of a specific parameter allows the controller 38 to behave like in a linear or normal mode of operation.

[0036] Although any non-linear flow characteristic may be implemented by the controller 38 when placed in the non-linear mode of operation, for the purposes of the present embodiment when in the non-linear mode of operation the movement of the joystick results in different flow behavior of the valves compared to when the controller is operating in the normal mode of operation. In particular, when the controller is configured to operate in the non-linear mode of operation the central position movement of the joystick changes the flow in the valve proportional but at a slower rate compared to when the joystick 34 is moved away from the central position in normal mode of operation. Movement of the joystick further away from the central position increases the ratio of flow rate to joystick movement with increased flow rate until maximum flow, for a given flow rate control setting, is obtained. Between the two zones (i.e. slow flow rate ratio and fast flow rate ratio) a form of knee point is created, as illustrated in Figure 3 and Figure 4.

[0037] The selection of where the knee point is positioned, that is to say the angle of movement of the joystick required to switch from one flow rate ratio to another flow rate ratio, is arbitrary and may be preconfigured in the controller 38 during manufacture or may be operator selectable. However, for the purposes of the present embodiment the knee point has been set at 25% of the maximum joystick movement for a given direction (i.e. for the 'retract' direction or the 'extend' direction). The knee point position may be different for different flow directions.

[0038] Preferably, two additional non-linear mode parameters are selectable. These parameters are i) a first non-linear mode parameter, being the portion of the absolute maximum flow rate at maximum deflection of the joystick (ymaxflow), where the standard ratio would be 100%, and ii) a second non-linear mode parameter, being the portion of the flow rate when the joystick is at the knee point position (yknee) and the absolute maximum flow rate is selected. The standard portion would be 50%, the resulting flow yknee at xknee (25%) would then be 12,5%.

[0039] The first non-linear mode parameter may be equal to the portion of the flow that is selected with the flow rate control 36 or through a HMI in the normal mode of operation.

[0040] The second non-linear mode parameter is in a first aspect independent from said first non-linear mode parameter because it relates to the absolute maximum flow rate. However, controller 38 limits the flow at the knee point to a value that would maximally be obtainable when operating in normal mode.

[0041] Selecting 100% as second non-linear mode parameter results in a substantially linear behavior and mimics a normal mode of operation.

[0042] For the purposes of the present embodiment, the equations used to define the flow rate characteristics/sensitivity when the controller is in the non-linear mode of operation are:

For the first zone (m1 = slow flow rate ratio) in non-linear mode:

$$y = m1x \qquad ,(0 \le x \le xknee) \wedge (m1 \le m2)$$

For the second zone (m2 = fast flow rate ratio) in non-linear mode:

$$y = m2(x - xknee) + yknee \qquad ,(xknee \le x \le 100) \wedge (m1 \le m2)$$

In normal mode (m3 = normal flow rate ratio):

$$y = m3x \qquad , (0 \le x \le 100)$$

[0043] However, any suitable means for defining the different flow rate ratio may be used.

[0044] Figures 3 and 4 illustrate different values for these parameters relative to the rate of change of flow rate with respect to deflection of the joystick, with the 'knee point' (i.e. the point at which the flow rate ratio/flow rate sensitivity changes) being set to 25% of the maximum joystick movement.

[0045] Figure 3 illustrates an example of the maximum flow rate, said first non-linear mode parameter, being set at 100% with three different values of the parameter 'flow rate when the joystick is at the knee point position as a portion of the maximum flow rate possible in view of the absolute maximum flow rate', said second non-linear mode parameter.

[0046] Line A illustrates an example of this second non-linear mode parameter value being set at 100% (i.e. there is the same proportion of flow in the central portion as in the outer portion, where there is a linear relationship of fluid flow over the whole range of joystick movement). Here m1 = m2 = m3.

[0047] Line B illustrates an example of this second non-linear mode parameter value being set at 50% (i.e. at the knee point the fluid flow is 50% of the portion of the maximum flow rate possible in view of the absolute maximum flow rate, which in this example is 12,5%, being 50% of 25). Here m1 < m2 and m1 < m3.

[0048] Line C illustrates an example of this second non-linear mode parameter value being set at 25% (i.e. at the knee point the fluid flow is 25% of the portion of the maximum flow rate possible in view of the absolute maximum flow rate, which in this example is 6,25%, being 25% of 25). Here m1 < m2 and m1 < m3.

[0049] Figure 4 illustrates a scenario where the first non-linear mode parameter, the maximum flow rate parameter, has been reduced from 100%, as in Figure 3, to 40%. For a maximum flow rate value of 40% in normal mode the flow rate at the knee point would only be 10%. Because of the limitation that the flow at the knee point is always equal or lower than in normal mode would be the case the requirement m1≤m3 is added, but because both m2 and m3 depend on a chosen maximum flow rate the requirement m1≤m2 has the same result. For a scenario where there is a linear relationship between flow rate and joystick movement over the whole range of movement of the joystick, this results in the line corresponding to Line B in Figure 4, where the second non-linear mode parameter has been set at 50%, becoming a straight line (i.e. the valve flow characteristics will be linear over the whole range of movement of the joystick).

[0050] Using the same reasoning Line A in Figure 4, with a second non-linear mode parameter of 100%, becomes a straight line, equal to line B of Figure 4.

[0051] However, line C, which corresponds to a second non-linear mode parameter value of 10%, has a flow rate of two and a half at the knee point (i.e. 10% of the flow rate when the joystick is at the knee point position as a portion of the maximum flow rate, i.e. 25, possible in view of the maximum flow rate, i.e. 100).

[0052] Accordingly, when in the non-linear mode of operation the operator has greater sensitivity when controlling an implement in the central region of the joystick, while also allowing rapid movement of the implement when the joystick is moved in the outer region.

[0053] Although the above illustration describes the controlling of fluid flow rates through a valve in a single direction, the present invention is equally applicable to the control of fluid flow through a valve in the opposite direction.

Claims

1. A method of controlling the flow rate through a hydraulic valve (40) in a non-linear mode, the method comprising defining a first range of positions of a control device (34), closest to a neutral position of the control device (34), corresponding to a first range of flow rates through the hydraulic valve (40), defining a second range of positions of the control device (34) corresponding to a second range of flow rates through the hydraulic valve (40), wherein the relationship between the first range of flow rates through the hydraulic valve (40) and the first range of positions of the control device (34) is substantially linear having a first ratio and the relationship between the second range of flow rates through the hydraulic valve (40) and the second range of positions of the control device (34) is substantially linear having a second ratio,
characterized in that the first ratio is smaller than or equal to the second ratio.

2. A method according to claim 1, the method further comprising the steps of defining the first ratio by a second non-linear mode parameter in relation to the absolute maximum flow rate of said hydraulic valve (40) and defining the second ratio by a first non-linear mode parameter in relation to a selected maximum flow rate of said hydraulic valve (40).

3. A method according to claim 2, the method further comprising the step of defining a knee-point as a predefined position of the control device (34) where the linear relationship of the flow rate through said hydraulic valve (40) changes from said first ratio to said second ratio.

4. A method according to claim 3, wherein the second non-linear mode parameter is a portion of the maximum flow rate possible at the knee-point and wherein the first non-linear mode parameter is a portion of the absolute maximum flow rate.

5. A method according to claim 4, wherein the first and second non-linera mode parameters are adjustable.

6. A method according to any of the preceding claims, wherein the first range of positions and the second range of positions correspond to flow rates in a first direction and a third range of positions and a fourth range of positions correspond to flow in a second direction, while the flow in the third and fourth range behaves similarly to the flow in the first and second range.

7. A controller (38) for controlling the flow rate through a hydraulic valve (40) in a non-linear mode, the controller (38) comprising a processor arranged to allocate a first range of positions of a control device (34), closest to the neutral position of the control device (34), to a first range of flow rates through the hydraulic valve (40), allocate a second range of positions of the control device (34) to a second range of flow rates through the hydraulic valve (40), wherein the relationship between the first range of flow rates through the hydraulic valve (40) and the first range of positions of the control device (34) is substantially linear having a first ratio and the relationship between the second range of flow rates through the hydraulic valve (40) and the second range of positions of the control device (34) is substantially linear having a second ratio, and **characterized in that** the first ratio is smaller or equal than the second ratio.

8. A controller (38) according to claim 7, wherein the first ratio is defined by a second non-linear mode parameter in relation to the absolute maximum flow rate of said hydraulic valve (40) and the second ratio is defined by a first non-linear mode parameter in relation to a selected maximum flow rate of the hydraulic valve (40).

9. A controller (38) according to claim 8, wherein a predefined position of the control device (34) is a knee-point where the linear relationship of the flow rate through the hydraulic valve (40) changes from the first ratio to the second ratio.

10. A controller (38) according to claim 9, wherein the second non-linear mode parameter is a portion of the maximum flow rate at the knee-point and wherein the first non-linear mode parameter is a portion of the absolute maximum flow rate.

11. A controller (38) according to claim 8, wherein the first and second non-linear mode parameters are adjustable.

12. A controller (38) according to claim 8 to 11, wherein the first range of positions and the second range of positions correspond to flow rates in the first direction and a third range of positions and a fourth range of positions correspond to a flow in a second direction, while the flow in the third and fourth range behave equal to the flow in the first and second range.

13. A controller (38) according to claim 12, wherein the processor is arranged to select a flow rate based on the position of the control device (34) based on whether the position of the control device (34) is within the first range of positions of the control device, the second range of positions of the control device, the third range of positions of the control device or the fourth range of positions of the control device.

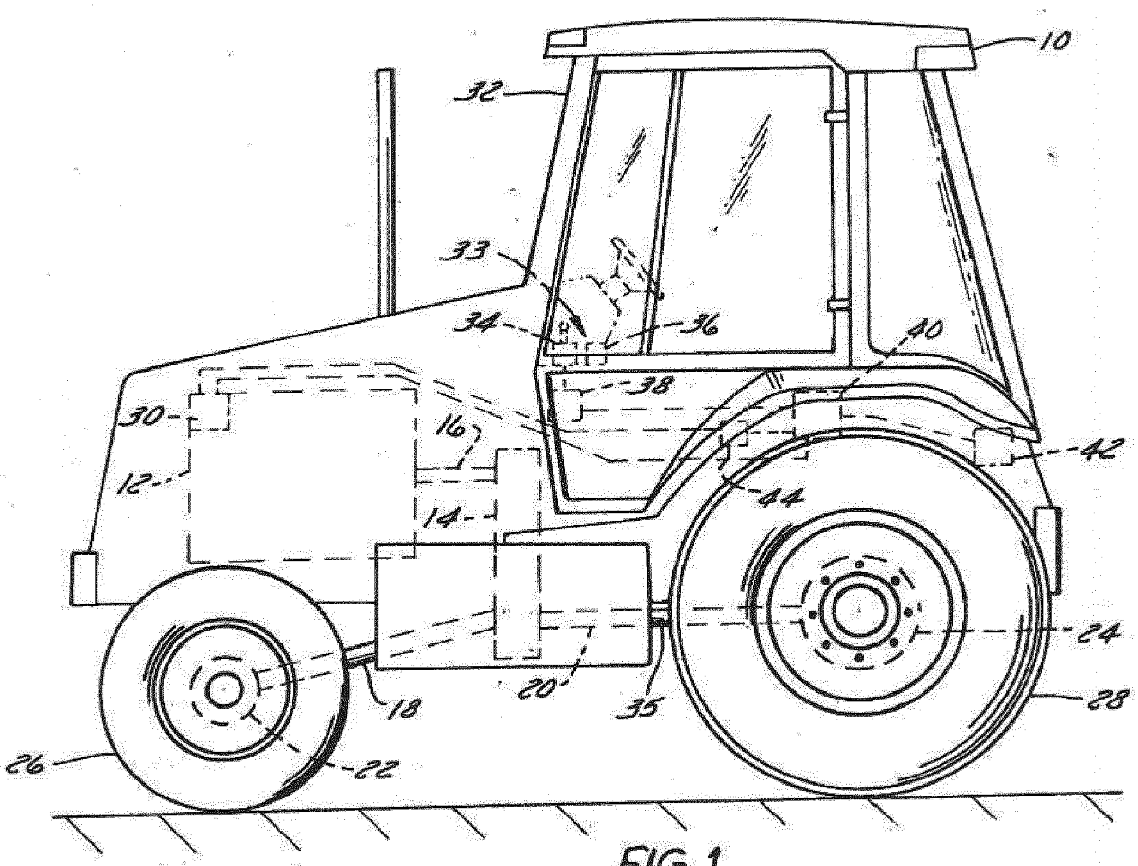


FIG. 1

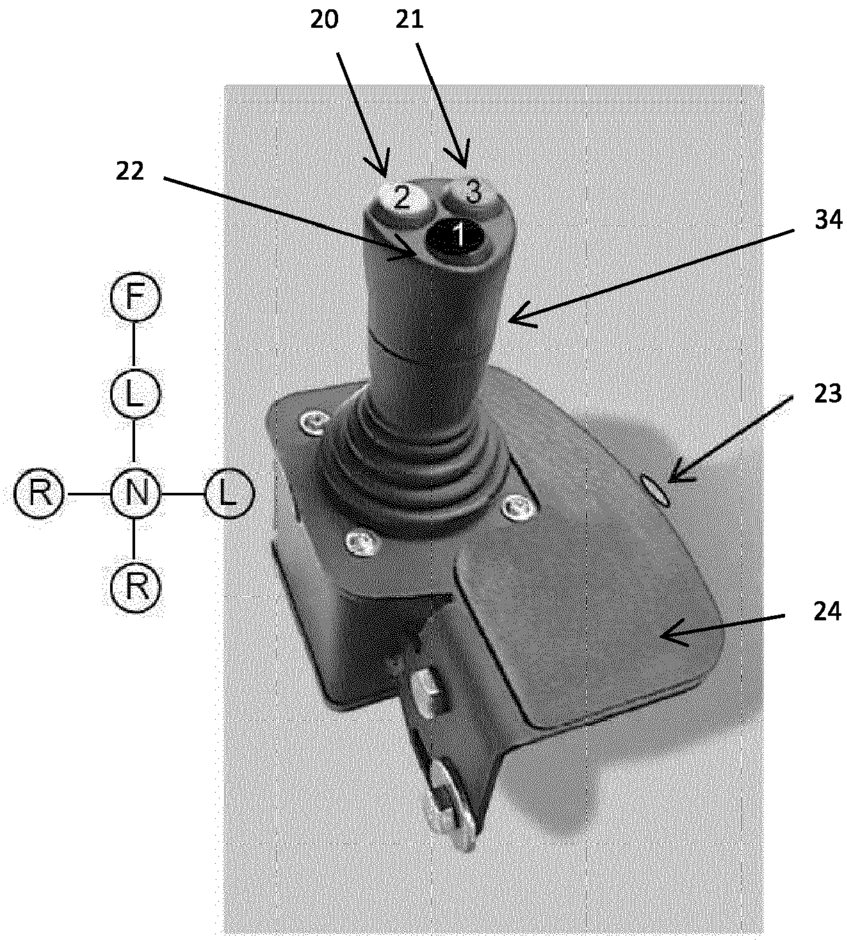
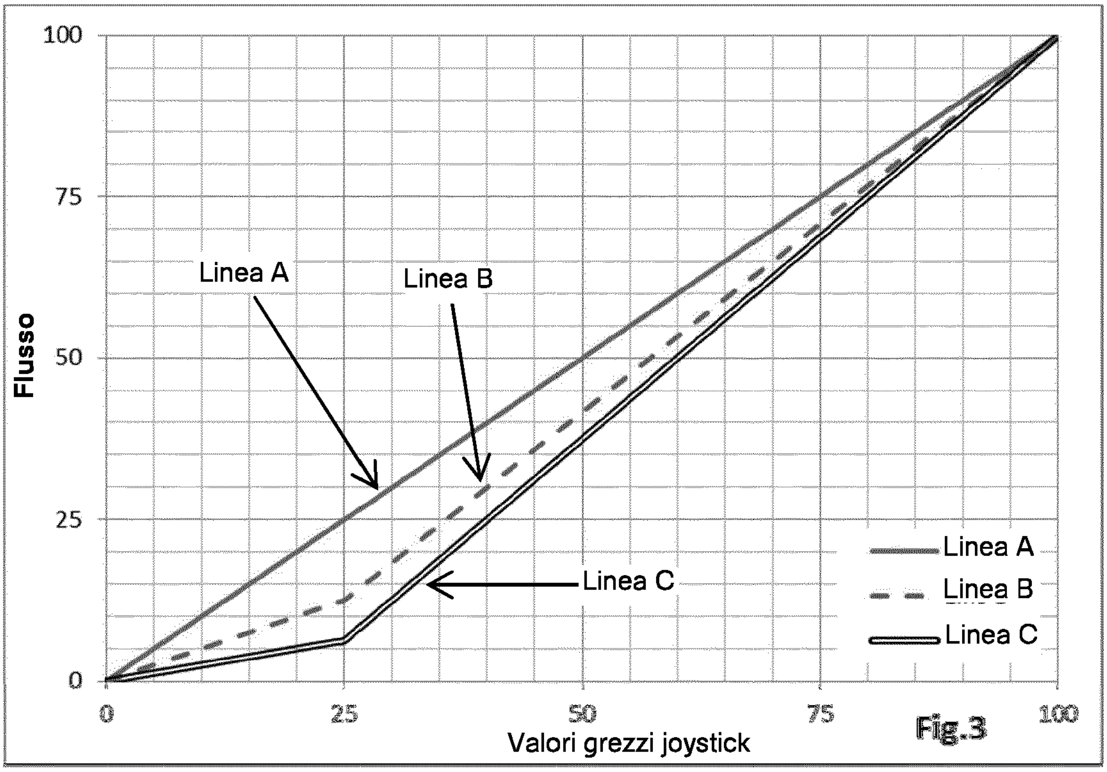


Fig. 2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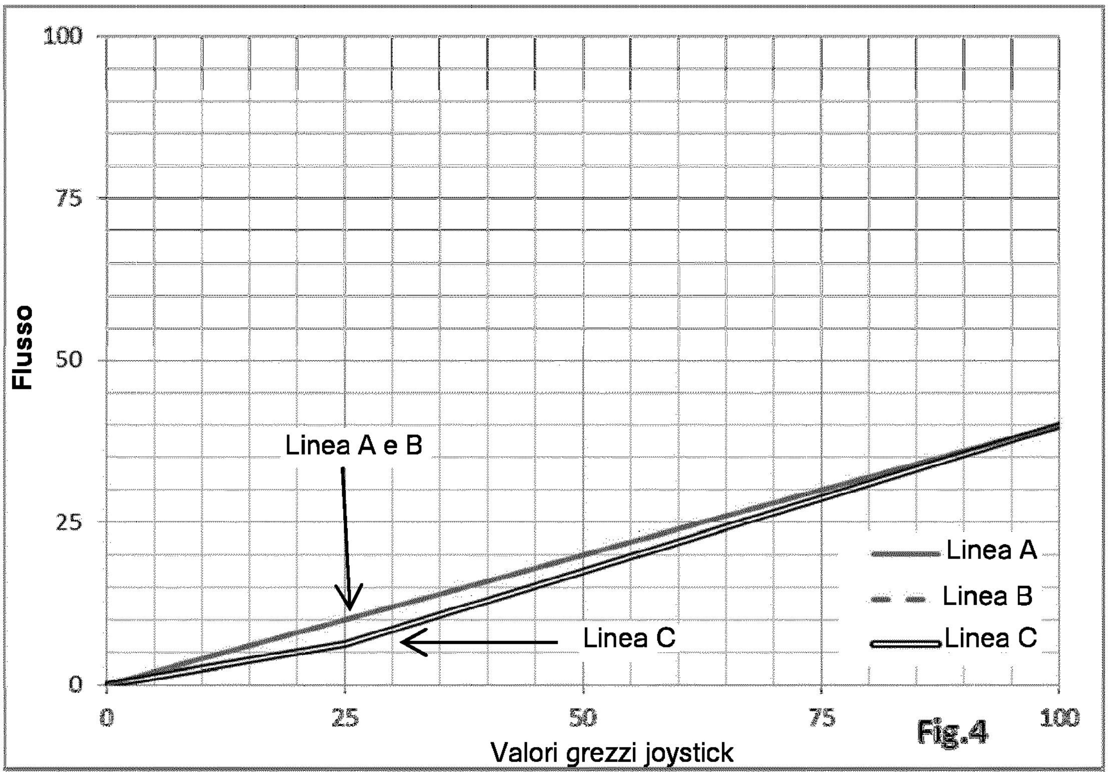
Valori grezzi joystick

Fig.3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Valori grezzi joystick

Fig.4

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EUROPEAN SEARCH REPORT

Application Number
EP 15 18 5693

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	US 2003/115866 A1 (PRICE ROBERT J [US]) 26 June 2003 (2003-06-26) * paragraphs [0025], [0033] - [0037] * -----	1-13	
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X	JP S61 206803 A (MITSUBISHI HEAVY IND LTD) 13 September 1986 (1986-09-13) * abstract; figures 1-3 * -----	1,7	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	2 February 2016	Toffolo, Olivier

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 18 5693

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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