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HYDRAULIC CONTROL SYSTEM IN WORKING MACHINES

Abstract

In a working machine in which a replaceable working attachment is attached to a tip portion of a working arm including a boom, even when the working attachment is replaced, lowering the boom at a lowering speed corresponding to an operation amount of an operating tool is controlled in a stable state. A monitor device for inputting information relating to a weight of an attached working attachment to a controller is provided. A map indicating a relationship between the weight of the replaceable working attachment (**8**) and a holding pressure of a boom cylinder head side oil chamber is provided in a controller. A holding pressure estimated value corresponding to the weight of the attached working attachment is obtained, based on the map. A configuration is adopted so that an opening area of a contraction side discharge opening of a control valve is controlled based on the holding pressure estimated value.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to a technical field of hydraulic control system used in working machines such as a hydraulic excavator.

BACKGROUND ART

[0002] Some working machines such as a hydraulic excavator include a working arm that includes a boom pivotally supported to be vertically swingable on a machine body and a stick supported to be swingable in a tip portion of the boom. A working attachment such as a bucket, a breaker, and a crusher is attached to the tip portion of the working arm to be replaceable. A configuration is adopted so that the boom is vertically moved by performing an expansion/contraction operation of a boom cylinder which expands by supplying oil to a head side oil chamber and contracts by discharging the oil from the head side oil chamber. In this working machine, a weight of the working arm or the working attachment acts as a force for lowering the boom. Accordingly, a pressure in the boom cylinder head side oil chamber is high. Therefore, a lowering speed of the boom is normally controlled by controlling a discharge flow rate from a boom cylinder head side oil chamber (meter-out control). In this case, for example, a control valve having a meter-out opening is provided in a discharge oil passage from the boom cylinder head side oil chamber, and a meter-out opening area of the control valve is controlled to increase or decrease depending on an operation amount of a boom operating tool. In this manner, the lowering speed of the boom is controlled to correspond to the operation amount of the operating tool.

[0003] However, when the lowering speed of the boom is controlled by controlling the discharge flow rate from the boom cylinder head side oil chamber as described above, the discharge flow rate from the head side oil chamber increases or decreases depending on not only the opening area of the meter-out opening of the control valve but also the pressure in the boom cylinder head side oil chamber. The pressure in the boom cylinder head side oil chamber is greatly changed depending on the weight of the working attachment which acts as the force for lowering the boom. Therefore, even when the opening areas of the meter-out openings are the same, that is, the operation amounts of the boom operating tools are the same, the lowering speed of the boom is changed depending on the weight of the attached working attachment, and the lowering speed of the boom cannot be accurately controlled, thereby causing a problem of poor operability.

[0004] Therefore, in the related art, as a technique for ensuring the boom lowering speed corresponding to the operation amount of the operating tool even when the working attachment is replaced, for example, the following techniques are known. There is a technique (for example, refer to PTL 1) disclosed as follows. A control valve (meter-out control valve) for controlling the discharge flow rate from the boom cylinder head side oil chamber, flow rate detection means for detecting a flow rate passing through the control valve, and a pressure sensor for detecting a holding pressure acting on the boom cylinder due to an external force are provided. Based on the detected holding pressure and the detected flow rate, the opening area of the control valve is controlled so that a pressure acting against the holding pressure is generated on an inlet side of the control valve. There is another technique (for example, refer to PTL 2) disclosed as follows. An electromagnetic proportional pressure reducing valve is provided in a regeneration circuit for supplying the oil discharged from the boom cylinder head side oil chamber to a rod side oil chamber when the boom is lowered. An opening degree of the electromagnetic proportional pressure reducing valve is controlled, based on a differential pressure between the pressure of the head side oil chamber which is detected by the pressure sensor and a preset target pressure value of the head side oil chamber.

PATENT LITERATURE

[0005] [PTL 1] JP-A-2003-106304 [0006] [PTL 2] JP-A-2010-78035

SUMMARY OF INVENTION

Technical Problem

[0007] However, both the techniques disclosed in PTLS 1 and 2 described above are configured to control the opening area of the meter-out control valve and the opening degree of the electromagnetic proportional pressure reducing valve, based on the pressure of the boom cylinder head side oil chamber which is frequently input from the pressure sensor. However, the pressure frequently input from the pressure sensor is a dynamic pressure, and there is a possibility that an unstable and unpredictable pressure value may be input depending on a usage status of the working attachment. When this dynamic pressure is used, the control valve or the electromagnetic proportional pressure reducing valve is irregularly operated, thereby causing a problem in that stable control cannot be performed. Here, this is the problem to be solved by the present invention.

Solution to Problem

[0008] In view of the above-described circumstances, the present invention is made to solve the problems. According to the invention in a first aspect, there is provided a boom lowering control system in a working machine including a working arm including at least a boom pivotally supported to be vertically swingable on a machine body, a replaceable working attachment attached to a tip portion of the working arm, a boom cylinder that causes the boom to vertically swing by expanding through oil supply to a head side oil chamber and contracting through oil discharge from the head side oil chamber, a control valve having a meter-out opening for controlling a discharge flow rate from a boom cylinder head side oil chamber, control means for controlling an operation of the control valve, and an operating tool operated to vertically move the boom. The boom lowering control system includes information input means for inputting information relating to a weight of the attached working attachment to the control means. The control means includes a map indicating a relationship between the weight of the replaceable working attachment and a holding pressure of the boom cylinder head side oil chamber, and obtains a holding pressure estimated value corresponding to the weight of the attached working attachment based on the map. Based on the holding pressure estimated value, the control means controls a meter-out opening area of the control valve so that the discharge flow rate from the boom cylinder head side oil chamber becomes a target discharge flow rate set in accordance with an operation amount of the operating tool when the boom is lowered.

[0009] According to the invention in a second aspect, in the first aspect of the boom lowering control system in a working machine, when the holding pressure estimated value corresponding to the weight of the attached working attachment is obtained, based on the map, the control means groups a holding pressure map value of the boom cylinder head side oil chamber into a plurality of groups in accordance with a magnitude of the holding pressure map value to set a representative value of the holding pressure in advance for each group and to set the holding pressure representative value of a group to which the holding pressure map value corresponding to the weight of the attached working attachment belongs, as the holding pressure estimated value corresponding to the weight of the attached working attachment.

[0010] According to the invention in a third aspect, in the first aspect of the boom lowering control system in a working machine, when the holding pressure estimated value corresponding to the weight of the attached working attachment is obtained, based on the map, the control means sets a representative value of the holding pressure in advance for each group by grouping the working attachments into a plurality of groups in accordance with a magnitude of the weight of the working attachment, and sets the holding pressure representative value of a group to which the attached working attachment belongs, as the holding pressure estimated value corresponding to the weight of the attached working attachment.

[0011] According to the invention in a fourth aspect, in any one of the first to third aspects of the boom lowering control system in a working machine, the map uses a linear relationship to indicate a relationship between the weight of the working attachment and the holding pressure of the boom cylinder head side oil chamber, based on a moment around a support shaft for pivotally supporting the boom to be swingable on the machine body.

[0012] According to the invention in a fifth aspect, in the first aspect of the boom lowering control system in a working machine, the weight of the working attachment includes a weight of a coupler used to attach the working attachment to the tip portion of the working arm.

[0013] According to the invention in a sixth aspect, in the first aspect of the boom lowering control system in a working machine, the working arm includes the boom and a stick pivotally supported to be swingable in a tip portion of the boom. A working attachment attached to the tip portion of the boom and a working attachment attached to a tip portion of the stick are provided as the working attachment. The map when the working attachment is attached to the tip portion of the boom and the map when the working attachment is attached to the tip portion of the stick are individually provided.

Advantageous Effects of Invention

[0014] According to the invention in the first aspect, even when the working attachment is replaced, lowering the boom at a lowering speed corresponding to an operation amount of the boom operating tool can be controlled in a stable state. Therefore, the first aspect can greatly contribute to improvement in operability.

[0015] According to the inventions in the second and third aspects, lowering the boom can be more stably controlled, and the second and third aspects are excellent in tuning.

[0016] According to the invention in the fourth aspect, it is possible to easily obtain the holding pressure map values corresponding to the weights of various working attachments.

[0017] According to the invention in the fifth aspect, in view of the weight of the coupler, the holding pressure estimated value is obtained. Therefore, a proper holding pressure estimated value can be obtained.

[0018] According to the invention in the sixth aspect, even when a working arm forming member to which the working attachment is attached is the boom or the stick, each proper holding pressure estimated value can be obtained.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0019] FIG. **1** is a side view of a hydraulic excavator.

[0020] FIG. **2** is a hydraulic circuit diagram of the hydraulic excavator.

[0021] FIG. **3** is a control block diagram of a boom lowering control system.

[0022] FIG. **4**(A) is a view showing a stick mounting map, and FIG. **4**(B) is a view showing a boom mounting map.

[0023] FIG. **5** is a table showing grouping of working attachments.

DESCRIPTION OF EMBODIMENTS

[0024] Now, an explanation is provided below about an embodiment of the present invention based on drawings.

[0025] First, the explanation about first embodiment of the present invention is provided based on FIGS. **1** to **4**; FIG. **1** is the drawing illustrating hydraulic excavator **1** as an example of construction machine according to the present invention, wherein the hydraulic excavator **1** includes a crawler type lower traveling body **2**, an upper swiveling body **3** swivelably supported above the lower traveling body **2**, and a front working part **4** mounted to the upper swiveling body **3** and others; and the front working part **4** includes a boom **5** whose base end part is supported vertically swingably by the upper swiveling body **3**, a stick **6** longitudinally swingably supported on an end part of the boom **5**, a bucket **7** swingably attached on the end part of the stick **6**, and others; wherein the hydraulic excavator **1** comprises various hydraulic actuators, such as boom/stick/bucket cylinders **8**, **9**, **10** for swinging the boom **5**, stick **6**, and bucket **7** respectively, left and right traveling motors (not shown) for moving the lower traveling body **2**, and a swiveling motor (not shown) for swiveling the upper swiveling body **3**. Furthermore, the hydraulic excavator **1** may selectively mount various optional attachments operating hydraulically, such as the breaker, crusher, grapple, and rotary cutting attachment (none is shown in FIG. **1**), in place of the bucket **7** according to a work content.

[0026] Furthermore, a reference numeral **14** represents a boom cylinder which performs an expansion/contraction operation to cause the boom **5** to vertically swing. The boom cylinder **14** is configured as follows. A head side end portion is supported to be swingable in a front part of the upper swiveling body **3** via a head side support shaft **14***c*. A rod side end portion is supported to be swingable in an intermediate portion in a length direction of the boom **5** via a rod side support shaft **14***d*. The boom cylinder **14** expands to raise the boom **5** by supplying oil to a head side oil chamber **14***a* (not shown in FIG. **1**) of the boom cylinder **14**, and contracts to lower the boom **5** by discharging the oil from the head side oil chamber **14***a*.

[0027] Here, FIG. **1** shows a bucket working as the working attachment **8** attached to the tip portion of the working arm **7**. However, depending on work contents of the hydraulic excavator **1**, various working tools such as a breaker (hammer), a compactor, a tilt bucket, a clamshell bucket, a thumb bucket, a grapple, and a crusher (all are not shown) can be replaced and attached to the tip portion of the working arm **7**. Furthermore, when the working tools are attached to the tip portion of the working arm **7**, in some cases, a coupler is not used unlike the bucket shown in FIG. **1**. However, in some cases, various couplers (not shown, a pin fixing coupler, a quick coupler, a coupler equipped with a hook, or a coupler which can tilt or rotate the working tool with respect to the working arm) may be used. Furthermore, when the coupler is used, a combination of the working tool and the coupler can be appropriately selected depending on a function of the coupler. In the present embodiment, when the coupler is used, the working tool and the coupler will be described as the working attachment **8**, and when the coupler is not used, the working tool will be described as the working attachment **8**.

[0028] In addition, FIG. **1** shows the boom **5** and the stick **6** as arm members forming the working arm **7** of the present invention, and the working attachment **8** is attached to the tip portion of the stick **6**. However, some of various working attachments **8** as described above are attached to the tip portion of the boom **5**. In this case, the working arm **7** does not include the stick **6**. In addition, the working arm **7** includes at least the boom **5** pivotally supported to be vertically swingable on the machine body. However, when other arm members forming the working arm **7** are provided in addition to the boom **5**, the arm member is not limited to the stick **6**, and various shapes or many arm members may be used.

[0029] Next, oil supply/discharge control of the boom cylinder **14** will be described with reference to a schematic hydraulic circuit diagram in FIG. **2**. In this case, a reference numeral **15** represents a hydraulic pump serving as a hydraulic supply source of the boom cylinder **14**, a reference numeral **16** represents a pilot pump serving as a supply source of a pilot pressure, a reference numeral **17** represents an oil tank, and a reference numeral **18** represents a control valve for performing oil supply/discharge control on the boom cylinder **14**. As the hydraulic circuit of the hydraulic excavator **1**, there are provided control circuits for other hydraulic actuators (the stick cylinder **10**, the bucket cylinder **11**, a swiveling motor (not shown) for swiveling of the upper swiveling body **3**,

or a traveling motor (not shown)) in addition to the boom cylinder **14**, and a circuit for controlling a discharge flow rate of the hydraulic pump. However, illustration and description thereof will be omitted.
[0030] The control valve (corresponding to a control valve of the present invention) **18** is a pilot operated three-position switching spool valve having expansion side and contraction side pilot ports **18***a* and **18***b*. In a state where a pilot pressure is not input to both the pilot ports **18***a* and **18***b*, the control valve **18** is located at a neutral position N where oil is not supplied to and discharged from the boom cylinder **14**. However, the control valve **18** is switched to an expansion side position X when the pilot pressure is input to the expansion side pilot port **18***a*. The oil supplied from the hydraulic pump **15** is supplied to the head side oil chamber **14***a* of the boom cylinder **14** via an expansion side supply opening **18***c*, and the oil discharged from a rod side oil chamber **14***b* is discharged to an oil tank **17** via an expansion side discharge opening **18***d*. On the other hand, the control valve **18** is switched to a contraction side position Y when the pilot pressure is input to the contraction side pilot port **18***b*. The oil supplied from the hydraulic pump **15** is supplied to the rod side oil chamber **14***b* of the boom cylinder **14** via a contraction side supply opening **18***e*, and the oil discharged from the head side oil chamber **14***a* is discharged to the oil tank **17** via a contraction side discharge opening **18***f* (corresponding to a meter-out opening of the present invention). Then, opening areas of the expansion side supply and discharge openings **18***c* and **18***d* and the contraction side supply and discharge openings **18***e* and **18***f* are controlled to increase or decrease by a movement stroke of a spool which moves in response to the pilot pressures input to the expansion side and contraction side pilot ports **18***a* and **18***b*.
[0031] Furthermore, in FIG. **2**, reference numerals **19** and **20** represent expansion side and contraction side electromagnetic proportional valves. The expansion side and contraction side electromagnetic proportional valves **19** and **20** each output the pilot pressures to the expansion side and contraction side pilot ports **18***a* and **18***b* of the control valve **18**, based on a control signal output from a controller **21** (to be described later). Then, the movement stroke of the spool of the control valve **18** increases or decreases in response to an increase or a decrease in the pilot pressures output from the expansion side and contraction side electromagnetic proportional valves **19** and **20**, and the opening areas of the expansion side supply and discharge openings **18***c* and **18***d* and the contraction side supply and discharge openings **18***e* and **18***f* are controlled to increase or decrease.
[0032] Here, when the boom **5** is lowered in the air (when the boom **5** is lowered in a state where the working attachment **8** is not on the ground), a weight of the front working part **4** (working arm **7** or working attachment **8**) acts as a contracting force of the boom cylinder **14**. Therefore, the pressure in the head side oil chamber **14***a* of the boom cylinder **14** is sufficiently higher than the pressure in the rod side oil chamber **14***b*. Therefore, a lowering speed of the boom **5** is controlled by controlling a discharge flow rate from the boom cylinder head side oil chamber **14***a* (meter-out control).
[0033] On the other hand, the controller (corresponding to control means of the present invention) **21** controls the control valves for various hydraulic actuators, and controls the discharge flow rate of the hydraulic pump **15**, based on an operation of operating tools for various hydraulic actuators. In the control performed by the controller **21**, a part relating to lowering control of the boom **5** will be described with reference to a control block diagram in FIG. **3**. Boom operation detection means **23** for detecting an operation direction and an operation amount of a boom operating tool **23***a* (corresponding to an operating tool of the present invention) operated to vertically move the monitor device **22** and the boom **5** is connected an input side of the controller **21**, and the contraction side electromagnetic proportional valve **20** is connected to an output side of the controller **21**. The controller **21** is provided with each unit such as an attachment arm member determination unit **25**, a working attachment weight calculation unit **26**, a holding pressure map unit **27**, a grouping unit **28**, a holding pressure estimated value setting part **29**, a target supply flow

rate setting part **30**, an opening area calculation unit **32**, and a valve control unit **33**.

[0034] The monitor device **22** corresponds to information input means of the present invention, and is disposed inside a cab **3***a* mounted on the upper swiveling body **3** in the present embodiment. The monitor device **22** has a display screen (not shown) for displaying information on various replaceable working attachments **8**, and operating means (not shown) such as a keyboard or touch panel, and stores information on the weight of various working attachments **8**. Then, the monitor device **22** is operated by an operator so that weight information on the attached working attachment **8** is input to the controller **21**. For example, working tools T**1** to Tn and couplers C**1** to Cn of the replaceable working attachment **8** are displayed on the display screen of the monitor device **22**. A working tool T and a coupler C (when the coupler is used) of the attached working attachment **8** are selected from among the working tools T**1** to Tn and the couplers C**1** to Cn by the operating means. In this manner, weights Wt and Wc of the attached working tool T and the attached coupler C are input to the controller **21**. In this case, with regard to a specific working tool to which a heavy load is applied when a heavy object is carried, not only information on the weight of the working tool itself but also information on a load weight corresponding to the working tool (for example, ½ of a maximum estimated load weight) is stored in the monitor device **22**. A configuration is adopted in which the weight obtained by adding the load weight to the weight of the working tool itself is output to the controller **21** as the weight Wt of the working tool.

[0035] Furthermore, the monitor device **22** is configured so that the operating means can select information on whether the working attachment **8** is attached to any arm member of the boom **5** and the stick **6**, and the information on the attachment arm member is input to the controller **21**.

[0036] In the present embodiment, the monitor device **22** is configured to store the information relating to the weights of the various working attachments **8**. However, a configuration can be adopted in which the information is stored in the controller **21** so that the monitor device **22** performs only a selection operation. Even in this case, the information relating to the weight of the attached working attachment **8** based on an operation of the monitor device **22** is input to the controller **21**.

[0037] Next, lowering control of the boom **5** which is performed by the controller **21** will be described with reference to FIG. **3**. The controller **21** inputs information output from the monitor device **22** to the attachment arm member determination unit **25** and the working attachment weight calculation unit **26**.

[0038] The attachment arm member determination unit **25** determines whether the working attachment **8** is attached to any one of the boom **5** and the stick **6**, based on the information input from the monitor device **22**, and outputs the determination result to the holding pressure map unit **27**.

[0039] In addition, the working attachment weight calculation unit **26** calculates the weight W of the working attachment **8**, based on the information input from the monitor device **22**. The weight W of the working attachment **8** is calculated by adding the weight Wt of the working tool T selected by the monitor device **22** and the weight Wc of the coupler C (W=Wt+Wc). Then, the calculated weight W of the working attachment **8** is output to the holding pressure map unit **27**.

[0040] The holding pressure map unit **27** is provided in advance with a map **35** indicating a relationship between the weight of the attachable working attachment **8** and the holding pressure of the head side oil chamber **14***a* of the boom cylinder **14**. In the map **35**, a boom mounting map **35***a* when the working attachment **8** is attached to the tip portion of the boom **5** and a stick mounting map **35***b* when the working attachment **8** is attached to the tip portion of the stick **6** are individually provided. Any one of the boom mounting map **35***a* and the stick mounting map **35***b* is selected, based on the determination result of the attachment arm member determination unit **25**.

[0041] Then, the holding pressure map unit **27** uses the selected boom mounting map **35***a* or the selected stick mounting map **35***b* to obtain a holding pressure map value Pm corresponding to the weight W of the working attachment **8** which is calculated by the working attachment weight

calculation unit **26**. Then, the holding pressure map value Pm is output to the grouping unit **28**.
[0042] Here, the map **35** (boom mounting map **35***a* and stick mounting map **35***b*) indicates the relationship between the weight W of the working attachment **8** and the holding pressure P of the boom cylinder head side oil chamber **14***a* in a linear relationship. Hereinafter, a method of preparing the map **35** will be described by using an example of the stick mounting map **35***b* when the replaceable working attachment **8** is attached to the tip portion of the stick **6**.
[0043] FIG. **1** shows the hydraulic excavator **1** when the following configuration is adopted. The working attachment **8** (bucket) is attached to the tip portion of the stick **6** via an attachment support shaft **8***a*, and a posture of the working arm **7** (boom **5** and stick **6**) is a maximum reach posture in which an axial height of the attachment support shaft **8***a* is the same as an axial height of a boom support shaft **5***a* (located on the same horizontal line H), and the axis of the attachment support shaft **8***a* is located at a farthest position from the axis of the boom support shaft **5***a*. The maximum reach posture is a posture in which a moment M around the boom support shaft **5***a* is maximized due to the weight of the front working part **4**. The moment M generated due to the weight of the front working part **4** in the maximum reach posture is obtained by the following formula (1).
[00001] $M=(W\times L\times g)+$ .Math. $(\mathrm{Wi}\times \mathrm{Li}\times g)$ (1)
[0044] In the formula (1) and formulas (3) and (4), W is the weight of the working attachment **8**, and L is a horizontal distance from an axial position of the boom support shaft **5***a* to a gravity center position of the working attachment **8** in the maximum reach posture. Wi (i=1, 2, 3, . . . x) is the weight of each of members A**1**, A**2**, A**3**, . . . Ax (in the front working part **4** shown in FIG. **1**, the boom **5**, the stick cylinder **10**, the stick **6**, the bucket cylinder **11**, a first link **12**, and a second link **13**) other than the working attachment **8** and forming the front working part **4**, Li (i=1, 2, 3, . . . x) is a horizontal distance from the axial position of the boom support shaft **5***a* in the maximum reach posture to the gravity center position of each of members A**1**, A**2**, A**3**, . . . Ax other than the working attachment **8** in the maximum reach posture, and g is acceleration of gravity. FIG. **1** shows horizontal distances L, L**1**, L**2**, L**3**, L**4**, L**5**, and L**6** from the axial position of the boom support shaft **5***a* to the axial positions of the working attachment **8**, the boom **5**, the stick cylinder **10**, the stick **6**, the bucket cylinder **11**, the first link **12**, and the second link **13**.
[0045] On the other hand, the moment M around the boom support shaft **5***a* which is generated due to the holding pressure P of the head side oil chamber **14***a* of the boom cylinder **14** is obtained by the formula (2).
[00002] $M=P\times S\times R$ (2)
[0046] In formula (2) and formulas (3) and (4), P is the holding pressure of the head side oil chamber **14***a* of the boom cylinder **14**, S is a head side pressure receiving area of a piston of the boom cylinder **14**, and R is a moment arm. The moment arm R is a length of a vertical line from the axis of the boom support shaft **5***a* to a line of action (straight line connecting the head side support shaft **14***c* and the rod side support shaft **14***d* of the boom cylinder **14**) of the boom cylinder **14**.
[0047] Then, based on a balance formula between the moment M around the boom support shaft **5***a* which is generated due to the weight of the front working part **4** and the moment M around the boom support shaft **5***a* which is generated due to the holding pressure P of the head side oil chamber **14***a* of the boom cylinder **14**, the holding pressure P of the head side oil chamber **14***a* of the boom cylinder **14** in the maximum reach posture of the front working part **4** is expressed by the formula (3).
[00003] $P=\{(W\times L\times g)/(S\times R)\}+\{$ .Math. $(\mathrm{Wi}\times \mathrm{Li}\times g)/(S\times R)\}$ (3)
[0048] Then, "Σ(Wi×Li×g)/(S×R)" in the formula (3) is an element other than the working attachment **8**, and is a constant value ({Σ(Wi×Li×g)/(S×R)}=b: constant) regardless of the attached working attachment **8**. Furthermore, when the horizontal distance L is considered constant from the axial position of the boom support shaft **5***a* to the gravity center position of the working attachment

8 even when the working attachment **8** is replaced, “(L×g)/(S×R)” in the formula (3) is also a constant value ({(L×g)/(S×R)}=a: constant). Therefore, formula (3) can be expressed as the formula (4).

[00004] $P=(a\times W)+b$ (4)

[0049] Then, “a” and “b” in the formula (4) are calculated and obtained, based on known data or measurement data of each member forming the front working part **4** and the boom cylinder **14**. In this manner, the stick mounting map **35***b* (refer to FIG. **4**(A)) is prepared to indicate a relationship between the weight W of the working attachment **8** and the holding pressure P of the boom cylinder head side oil chamber **14***a* in a linear relationship.

[0050] In addition, when the working attachment **8** is attached to the tip portion of the boom **5**, values of “a” and “b” in the formula (4) are different. However, similarly, the boom mounting map **35***a* (refer to FIG. **4**(B)) is prepared to indicate a relationship between the weight W of the working attachment **8** and the holding pressure P of the boom cylinder head side oil chamber **14***a* in a linear relationship. In this case, the attachment support shaft **8***a* is provided in the tip portion of the boom **5**, and the maximum reach posture is a posture in which the axial height of the attachment support shaft **8***a* is the same height as the axial height of the boom support shaft **5***a* (located on the same horizontal line), and the axis of the attachment support shaft **8***a* is located at the farthest position from the axis of the boom support shaft **5***a*.

[0051] Then, as described above, the map **35** (boom mounting map **35***a* or stick mounting map **35***b*) is used to obtain the holding pressure map value Pm corresponding to the weight W of the attached working attachment **8** in the holding pressure map unit **27**, and the holding pressure map value Pm is output to the grouping unit **28**. In the grouping unit **28**, the holding pressure map value Pm is grouped into a plurality of groups (three groups of first, second, and third groups G**1**, G**2**, and G**3** in the present embodiment) in accordance with a magnitude of the holding pressure map value Pm. In this case, the threshold value setting part **28***a* sets the same number of holding pressure threshold values Pt (in the present embodiment, first, second, and third holding pressure threshold values Pt**1**, Pt**2**, and Pt**3** (Pt**1**≤Pt**2**≤Pt**3**)) as the number of groups, and the map value Pm of the holding pressure is grouped by using the holding pressure threshold values. In the present embodiment, when the holding pressure map value Pm is equal to or smaller than the first holding pressure threshold value Pt**1** (Pm≤Pt**1**), the holding pressure map value Pm is grouped into the first group G**1**. When the holding pressure map value Pm exceeds the first holding pressure threshold value Pt**1** and is equal to or smaller than the second holding pressure threshold value Pt**2** (Pt**1**<Pm≤Pt**2**), the holding pressure map value Pm is grouped into the second group G**2**. When the holding pressure map value Pm exceeds the second holding pressure threshold value Pt**2** and is equal to or smaller than the third holding pressure threshold value Pt**3** (Pt**2**<Pm≤Pt**3**), the holding pressure map value Pm is grouped into the third group G**3**. The holding pressure threshold values can be appropriately changed in accordance with a size or specifications of the hydraulic excavator **1**, for example, by using external input means such as the monitor device **22**. Then, the grouping unit **28** outputs a grouping result, that is, whether the holding pressure map value Pm belongs to any one of the first, second, and third groups, to the holding pressure estimated value setting part **29**.

[0052] Here, FIG. **5** shows a result example in each case where various types and sizes of replaceable working tools T**1** to T**25** (a bucket, a breaker (hammer), a compactor, a tilt bucket, a clamshell bucket, a thumb bucket, a grapple, and a crusher) are attached to the tip portion of the stick **6** or the boom **5** without any coupler or via couplers C**1** to C**9** which can be combined with the working tools T**1** to T**25**. In each case, the map **35** (boom mounting map **35***a* or stick mounting map **35***b*) is used to obtain the holding pressure map value Pm corresponding to the weight W of the working attachment **8** (working tool T and coupler C), and the holding pressure map value Pm is grouped (first, second, and third groups G**1**, G**2**, and G**3**).

[0053] On the other hand, when the group to which the holding pressure map value Pm belongs is input from the grouping unit **28**, the holding pressure estimated value setting part **29** sets a holding pressure representative value set in advance for each group, as a holding pressure estimated value P corresponding to the attached working attachment **8**, and outputs the holding pressure estimated value P to the opening area calculation unit **32**. In the present embodiment, the holding pressure representative value of each group is set to the maximum holding pressure map value Pm of the group, that is, the first group G**1** is set to the first holding pressure threshold value Pt**1**, the second group G**2** is set to the second holding pressure threshold value Pt**2**, and the third group G**3** is set to the third holding pressure threshold value Pt**3**, respectively. The first, second, and third holding pressure threshold values Pt**1**, Pt**2**, and Pt**3** respectively become the holding pressure estimated value P of the working attachment **8** belonging to the first, second, and third groups G**1**, G**2**, and G**3**.
[0054] On the other hand, as described above, the boom operation detection means **23** for detecting the operation of the boom operating tool **23***a* is connected to the input side of the controller **21**. However, an operation signal output from the boom operation detection means **23** is input to the target supply flow rate setting part **30** of the controller **21**. When the operation signal on the boom lowering side is input from the boom operation detection means **23**, in order to realize the boom lowering speed corresponding to the operation amount of the boom operating tool **23***a*, the target supply flow rate setting part **30** sets a target discharge flow rate Qt from the head side oil chamber **14***a* of the boom cylinder **14** in accordance with the operation amount of the boom operating tool **23***a*. Then, the target discharge flow rate Qt is output to the opening area calculation unit **32**.
[0055] Based on the holding pressure estimated value P input from the holding pressure estimated value setting part **29** and the target discharge flow rate Qt input from the target supply flow rate setting part **30**, the opening area calculation unit **32** uses formula (6) derived from formula (5) of orifice shown below, and calculates the opening area of the contraction side discharge opening **18***f* of the control valve **18**.
[00005] $Q = C \times A \times \surd(\quad P / \quad)$ (5)
[00006] $A = (\surd \quad / C) \times (\mathrm{Qt} / \surd P)$ (6)
[0056] Where in the formula (5), Q is an orifice flow rate, A is an orifice opening area, ΔP is an orifice differential pressure, C is a factor, and ρ is fluid density.
[0057] In addition, in the formula (6), A is the opening area of the contraction side discharge opening **18***f* of the control valve **18**, Qt is the target discharge flow rate set by the target supply flow rate setting part **30**, P is the holding pressure estimated value set by the holding pressure estimated value setting part **29**, C is a flow coefficient, and p is fluid density. In the formula (6), the pressure (tank pressure) on the downstream side of the contraction side discharge opening **18***f* is regarded as “0 (zero)”. In addition, a value of “√ρ/C” in the formula (6) is regarded as a constant. The value of “√ρ/C” is set by a constant setting part **32***a* which uses external input means such as the monitor device **22**, for example, and input to the opening area calculation unit **32**.
[0058] Then, the opening area of the contraction side discharge opening **18***f* of the control valve **18** which is calculated by using the formula (6) is output to the valve control unit **33**.
[0059] Based on the opening area of the contraction side discharge opening **18***f* which is input from the opening area calculation unit **32**, the valve control unit **33** obtains a spool movement stroke of the control valve **18** corresponding to the opening area. An input pilot pressure to the contraction side pilot port **18***b* for moving a spool up to the stroke is further obtained, and a current command value to the contraction side electromagnetic proportional valve **20** for outputting the pilot pressure is further obtained. In this manner, the current command value is output to the contraction side electromagnetic proportional valve **20** as a control signal. In this manner, the contraction side discharge opening **18***f* of the control valve **18** is controlled to have the opening area calculated by the opening area calculation unit **32**. Then, since the opening area of the contraction side discharge

opening **18***f* of the control valve **18** is controlled in this way, the discharge flow rate from the head side oil chamber **14***a* of the boom cylinder **14** can be controlled to be the target discharge flow rate Qt set in accordance with the operation of the boom operating tool **23***a*.

[0060] In the embodiment constructed as described above, the hydraulic excavator **1** includes the working arm **7** including at least the boom **5** pivotally supported to be vertically swingable on the upper swiveling body (machine body), the replaceable working attachment **8** attached to the tip portion of the working arm **7**, the boom cylinder **14** that causes the boom **5** to vertically swing by expanding through oil supply to the head side oil chamber **14***a* and contracting through oil discharge from the rod side oil chamber **14***b*, and, the control valve (control valve) **18** having the contraction side discharge opening (meter-out opening) **18***f* for controlling the discharge flow rate from the head side oil chamber **14***a* of the boom cylinder **14**, the controller (control means) **21** for controlling the operation of the control valve **18**, and the boom operating tool **23***a* operated to vertically move the boom **5**. Furthermore, the hydraulic excavator **1** is provided with the monitor device (information input means) **22** for inputting the information relating to the weight of the attached working attachment **8** to the controller **21**. Then, the controller **21** includes the map **35** indicating the relationship between the weight of the replaceable working attachment **8** and the holding pressure of the boom cylinder head side oil chamber **14***a*. The controller **21** obtains the holding pressure estimated value corresponding to the weight of the attached working attachment **8** based on the map **35**. Based on the holding pressure estimated value, the controller **21** controls the opening area of the contraction side discharge opening **18***f* of the control valve **18** so that the discharge flow rate from the boom cylinder head side oil chamber **14***a* becomes the target discharge flow rate set in accordance with the operation amount of the boom operating tool **23***a* when the boom **5** is lowered.

[0061] In this way, in the embodiment of the present invention, the opening area of the contraction side discharge opening **18***f* of the control valve **18** when the boom **5** is lowered is controlled, based on the holding pressure estimated value corresponding to the weight of the working attachment **8**. In this manner, even when the weight of the working attachment **8** is changed due to replacement of the working attachment **8**, the opening area can be controlled so that the discharge flow rate from the boom cylinder **14** is set to the target discharge flow rate set in accordance with the operation amount of the boom operating tool **23***a*, that is, so that the boom **5** can be lowered at the lowering speed corresponding to the operation amount of the boom operating tool **23***a*. However, in this case, the holding pressure estimated value is a fixed value obtained corresponding to the weight of the attached working attachment **8** based on the map **35** provided in the controller **21**. Therefore, as in a case where the discharge flow rate is controlled by using a pressure detection value of the boom cylinder head side oil chamber **14***a* which is frequently input from the pressure sensor as the holding pressure, a stable discharge flow rate can be controlled without any problem that control is unstable after the opening area of the contraction side discharge opening **18***f* is irregularly changed in response to the pressure detection value. As a result, even when the working attachment **8** is replaced, the boom **5** can be lowered in a stable state at the lowering speed corresponding to the operation amount of the boom operating tool **23***a*. Therefore, this configuration can greatly contribute to improvement in operability.

[0062] Furthermore, in this configuration, when the controller **21** obtains the holding pressure estimated value corresponding to the weight of the attached working attachment **8** based on the map **35**, the controller **21** groups the holding pressure map value of the boom cylinder head side oil chamber **14***a* into the plurality of groups (three groups of the first, second, and third groups G**1**, G**2**, and G**3** in the present embodiment) in accordance with the magnitude of the holding pressure map value, sets the representative value (first, second, and third holding pressure threshold values Pt**1**, Pt**2**, and Pt**3** in the present embodiment) of the holding pressure in advance for each group, and sets the holding pressure representative value of the group to which the holding pressure map value corresponding to the weight of the attached working attachment **8** belongs, as the holding pressure estimated value corresponding to the weight of the attached working attachment **8**. In this way, the holding pressure map value is grouped, and the holding pressure representative value of each group is set as the holding pressure estimated value used for controlling the discharge flow rate. In this manner, lowering the boom can be more stably controlled, and this configuration is excellent in tuning.

[0063] Furthermore, the map **35** indicates the relationship between the weight of the working attachment **8** and the holding pressure of the boom cylinder head side oil chamber **14***a* in a linear relationship, based on the moment around the support shaft (boom support shaft **5***a*) which pivotally supports the boom **5** on the machine body to be swingable. Since the map **35** indicating the linear relationship is used in this way, the holding pressure map values corresponding to the weights of various working attachments **8** can be easily obtained.

[0064] In addition, in this configuration, the weight of the working attachment **8** includes the weight of the coupler used for attaching the working attachment **8** to the tip portion of the working arm **7**. In this manner, even when the coupler is used, in view of the weight of the coupler, the holding pressure estimated value is obtained so that a proper holding pressure estimated value can be obtained.

[0065] In addition, in the present embodiment, the working arm **7** includes the boom **5** and the stick **6** pivotally supported to be swingable in the tip portion of the boom **5**. On the other hand, the working attachment **8** attached to the tip portion of the boom **5** and the working attachment **8** attached to the tip portion of the stick **6** are provided as the working attachment. Then, in the map **35** indicating the relationship between the weight of the replaceable working attachment **8** and the holding pressure, the map (boom mounting map **35***a*) when the working attachment **8** is attached to the tip portion of the boom **5** and the map (stick mounting map **35***b*) when the working attachment is attached to the tip portion of the stick **6** are individually provided. In this way, the map **35** is individually provided in accordance with the working arm forming member (boom **5** or stick **6**) to which the working attachment **8** is attached. Therefore, even when the working arm forming member to which the working attachment **8** is attached is the boom **5** or the stick **6**, each proper holding pressure estimated value can be obtained.

[0066] As a matter of fact, the present embodiment is not limited to the above-described embodiment. For example, when the holding pressure estimated value corresponding to the weight of the attached working attachment is obtained, based on the map, the working attachments are grouped into the plurality of groups in accordance with the magnitude of the weight of the working attachment, and the representative value of the holding pressure is set in advance for each group. The map is used to obtain the holding pressure representative value of the group to which the attached working attachment belongs. In this manner, a configuration can be adopted in which the holding pressure representative value is set as the holding pressure estimated value corresponding to the weight of the attached working attachment. Since the working attachments are grouped in this way and the holding pressure representative value is set as the holding pressure estimated value, as in a case of the above-described embodiment, lowering the boom can be more stably controlled, and this configuration is excellent in tuning.

[0067] In addition, in the above-described embodiment, when the opening area calculation unit **32** of the controller **21** calculates the opening area of the contraction side discharge opening (meter-out opening) **18***f*, the opening area is calculated by using formula (6) as described above. However, the opening area can be more accurately controlled in such a manner that a correction value obtained in view of a pressure loss of the control valve **18** or a hydraulic pipe is added to this calculation.

[0068] Furthermore, in the above-described embodiment, the map indicating the relationship between the weight of the working attachment and the holding pressure of the boom cylinder head side oil chamber is prepared on an assumption that the working arm is in the maximum reach posture. The reason is as follows. It is assumed that the holding pressure is highest in the maximum reach posture, and the control is performed on an assumption that the holding pressure is highest.

In this manner, it is possible to reliably avoid the lowering speed of the boom from being faster than an expected speed. However, in some cases, depending on the work contents performed by the working machine, it is conceivable that the holding pressure is higher. Therefore, in order to cope with this case, the correction value can be added to the map.

[0069] In addition, the present invention is not limited to the hydraulic excavator, and can be applied to boom lowering control systems for various types of working machines in which the replaceable working attachment is attached to the tip portion of the working arm including the boom.

INDUSTRIAL APPLICABILITY

[0070] This invention is available for use in the hydraulic control system of working machine such as hydraulic shovel.

Claims

1. A boom lowering control system in a working machine including a working arm including at least a boom pivotally supported to be vertically swingable on a machine body; a replaceable working attachment attached to a tip portion of the working arm; a boom cylinder that causes the boom to vertically swing by expanding through oil supply to a head side oil chamber and contracting through oil discharge from the head side oil chamber; a control valve having a meter-out opening for controlling a discharge flow rate from a boom cylinder head side oil chamber; control means for controlling an operation of the control valve; and an operating tool operated to vertically move the boom, the boom lowering control system comprising: information input means for inputting information relating to a weight of the attached working attachment to the control means, wherein the control means includes a map indicating a relationship between the weight of the replaceable working attachment and a holding pressure of the boom cylinder head side oil chamber, and obtains a holding pressure estimated value corresponding to the weight of the attached working attachment based on the map, and based on the holding pressure estimated value, the control means controls a meter-out opening area of the control valve so that the discharge flow rate from the boom cylinder head side oil chamber becomes a target discharge flow rate set in accordance with an operation amount of the operating tool when the boom is lowered.

2. The boom lowering control system in a working machine according to claim 1, wherein when the holding pressure estimated value corresponding to the weight of the attached working attachment is obtained, based on the map, the control means groups a holding pressure map value of the boom cylinder head side oil chamber into a plurality of groups in accordance with a magnitude of the holding pressure map value to set a representative value of the holding pressure in advance for each group and to set the holding pressure representative value of a group to which the holding pressure map value corresponding to the weight of the attached working attachment belongs, as the holding pressure estimated value corresponding to the weight of the attached working attachment.

3. The boom lowering control system in a working machine according to claim 1, wherein when the holding pressure estimated value corresponding to the weight of the attached working attachment is obtained, based on the map, the control means sets a representative value of the holding pressure in advance for each group by grouping the working attachments into a plurality of groups in accordance with a magnitude of the weight of the working attachment, and sets the holding pressure representative value of a group to which the attached working attachment belongs, as the holding pressure estimated value corresponding to the weight of the attached working attachment.

4. The boom lowering control system in a working machine according to claim 1, wherein the map uses a linear relationship to indicate a relationship between the weight of the working attachment and the holding pressure of the boom cylinder head side oil chamber, based on a moment around a support shaft for pivotally supporting the boom to be swingable on the machine body.

5. The boom lowering control system in a working machine according to claim 1, wherein the weight of the working attachment includes a weight of a coupler used to attach the working attachment to the tip portion of the working arm.

6. The boom lowering control system in a working machine according to claim 1, wherein the working arm includes the boom and a stick pivotally supported to be swingable in a tip portion of the boom, a working attachment attached to the tip portion of the boom and a working attachment attached to a tip portion of the stick are provided as the working attachment, and the map when the working attachment is attached to the tip portion of the boom and the map when the working attachment is attached to the tip portion of the stick are individually provided.