SPECIFICATION

TITLE OF INVENTION : DEEP FOUNDATION EXCAVATION MACHINE

TECHNICAL FIELD

[0001] The present disclosure relates to a deep foundation excavation machine suitably used for excavating a vertical shaft.

BACKGROUND ART

[0002] At construction sites for high-rise buildings, deep foundation excavation machines are used to excavate deep vertical shafts in the ground in order to construct deep foundation piles that transfer the weight of a building to a bearing stratum in the ground. The deep foundation excavation machine includes a work device provided on a self-propelled vehicle body. The work device includes a boom attached to the self-propelled vehicle body, an arm attached to a distal end of the boom, a bucket raising-lowering and opening-closing device attached to the arm, and a clamshell bucket. The clamshell bucket is supported by the bucket raising-lowering and opening-closing device via a raising-lowering rope and an opening-closing rope, and performs raising-lowering and opening-closing operations through extension and contraction operation of a raising-lowering cylinder and an opening-closing cylinder constituting the bucket raising-lowering and opening-closing device, thereby excavating a vertical shaft.

[0003] During excavation of a vertical shaft, the clamshell bucket is lowered to the ground in an open state. After the clamshell

bucket lands on the ground, the raising-lowering rope and the opening-closing rope are loosened, allowing the clamshell bucket to dig into the ground by its own weight. By closing the clamshell bucket in this state, a large amount of earth and sand is excavated. In this case, when the clamshell bucket digs into the ground, loosening of the raising-lowering rope is removed, whereas loosening of the opening-closing rope is not removed. Thus, additional time is required to close the clamshell bucket by the opening-closing cylinder due to the loosening of the opening-closing rope.

[0004] In contrast, a deep foundation excavation machine equipped with a loosening removal cylinder configured to remove loosening of an opening-closing rope before closing the clamshell bucket has been proposed. By operating the loosening removal cylinder to remove the loosening of the opening-closing rope, the clamshell bucket that has dug into the ground can be quickly closed by the opening-closing cylinder to scoop up earth and sand, thereby allowing excavation to be performed efficiently (see Patent Literatures 1 and 2).

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0005] Patent Literature 1: JP 7166308 B

Patent Literature 2: JP 7166487 B

SUMMARY OF THE INVENTION

[0006] However, the deep foundation excavation machines according to Patent Literatures 1 and 2 include a dedicated loosening removal

cylinder configured to remove loosening of an opening-closing rope. As a result, the operator needs to perform a cumbersome operation of operating the loosening removal cylinder to remove the loosening of the opening-closing rope before closing the clamshell bucket by the opening-closing cylinder after the clamshell bucket lands. Additionally, after the loosening of the opening-closing rope is removed by the loosening removal cylinder, an unnecessary time lag occurs before the clamshell bucket is closed by the opening-closing cylinder. As a result, excavation efficiency decreases.

[0007] Furthermore, extension and contraction of the loosening removal cylinder is transmitted to an opening-closing rope via sheaves, thereby increasing bending frequency of the opening-closing rope by the sheaves and increasing a length of the opening-closing rope. As a result, an opening-closing speed of the clamshell bucket due to raising and lowering of the opening-closing rope decreases, thereby reducing excavation efficiency.

[0008] On the other hand, in order to increase excavation efficiency, it is desirable to increase a raising-lowering speed of the clamshell bucket. For this reason, for example, a flow rate of hydraulic fluid supplied to a raising-lowering cylinder may be increased to increase the extension and contraction speed of the raising-lowering cylinder. However, since a plurality of sheaves are provided around a raising-lowering rope, movement of the raising-lowering rope and the opening-closing rope may not keep up with the extension and contraction speed of the raising-lowering cylinder. In this case, the raising-lowering

rope and the opening-closing rope may be loosened, come into contact with surrounding structures, and be damaged.

[0009] Also, when loading excavated earth and sand onto a dump truck bed or the like, the clamshell bucket raised from a vertical shaft to ground level needs to be lowered to match a height of the dump truck bed, or is used to level a mound of earth and sand loaded onto the dump truck bed with the clamshell bucket. In this case, the operator needs to precisely raise and lower the clamshell bucket with respect to the dump truck bed to prevent contact between the clamshell bucket and the dump truck bed, thereby reducing excavation efficiency.

[0010] Furthermore, a plurality of sheaves are attached to the clamshell bucket, and the opening-closing rope wound around the plurality of sheaves is raised and lowered by extension and contraction of an opening-closing cylinder to open and close the clamshell bucket. Therefore, if the number of sheaves is increased to increase an excavation force of the clamshell bucket, extension and contraction speed of the opening-closing cylinder may become excessive. As a result, movement of the opening-closing rope cannot keep up with the extension and contraction speed of the opening-closing cylinder, causing the opening-closing rope to be loosened, come into contact with surrounding structures, and be damaged.

[0011] The object of the present disclosure is to provide a deep foundation excavation machine capable of improving excavation efficiency.

[0012] The deep foundation excavation machine according to the present disclosure comprises a self-propelled vehicle body and

a work device attached to the self-propelled vehicle body. The work device includes an arm rotatably attached to the self-propelled vehicle body, a clamshell bucket raisably and lowerably attached to the arm for excavating a vertical shaft, and a bucket raising-lowering and opening-closing device attached to the arm for raising-lowering, opening, and closing the clamshell bucket. The bucket raising-lowering and opening-closing device includes a raising-lowering cylinder attached to the arm; a first raising-lowering sheave and a first opening-closing sheave attached to one end side of the raising-lowering cylinder and movable in an extension-contraction direction of the raising-lowering cylinder; a second raising-lowering sheave attached to the arm at a distance from the first raising-lowering sheave; a second opening-closing sheave attached to the arm at a distance from the first opening-closing sheave; an opening-closing cylinder that opens and closes the clamshell bucket by moving the second opening-closing sheave toward and away from the first opening-closing sheave; a raising-lowering rope having one end attached to the arm and another end attached to the clamshell bucket, with an intermediate portion wound around the first and the second raising-lowering sheaves; and an opening-closing rope having one end attached to the arm and another end attached to the clamshell bucket, with an intermediate portion wound around the first and the second opening-closing sheaves. A stroke length of the opening-closing cylinder is set to a value equal to or greater than a sum of a stroke length corresponding to an opening-closing range of the clamshell bucket and a stroke length corresponding to a loosening amount of the opening-closing

rope that occurs between when the clamshell bucket lands and when the raising-lowering cylinder stops. The deep foundation excavation machine further comprises at least one of: an opening-closing cylinder relief valve that relieves excessive pressure in the opening-closing cylinder when a weight of the clamshell bucket acts on the opening-closing rope; a raising-lowering flow rate adjustment device capable of varying a flow rate of hydraulic fluid supplied to the raising-lowering cylinder at a time of raising the clamshell bucket and a flow rate of hydraulic fluid supplied to the raising-lowering cylinder at a time of lowering the clamshell bucket; and a raising-lowering speed adjustment device that adjusts a raising-lowering speed of the clamshell bucket at a time of raising and at a time of lowering the clamshell bucket.

[0013] According to the present disclosure, excavation efficiency can be improved when excavating a vertical shaft using a clamshell bucket.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014][FIG. 1] is a left side view showing a deep foundation excavation machine according to an embodiment of the present disclosure.

[FIG. 2] is a schematic diagram showing a bucket raising-lowering and opening-closing device.

[FIG. 3] is a hydraulic circuit diagram of the bucket raising-lowering and opening-closing device.

[FIG. 4] is an operation description diagram schematically showing an operation when a clamshell bucket is lowered.

[FIG. 5] is an operation description diagram showing a state in which the clamshell bucket has landed on the ground.

[FIG. 6] is an operation description diagram showing a state after the clamshell bucket lands and a raising-lowering rope and an opening-closing rope are loosened.

[FIG. 7] is an operation description diagram showing a state in which loosening of an opening-closing rope is removed before closing the clamshell bucket.

[FIG. 8] is an operation description diagram showing a state in which the clamshell bucket is closed to excavate earth and sand.

[FIG. 9] is an operation description diagram showing a state in which loosening of a raising-lowering rope is removed before raising the clamshell bucket.

[FIG. 10] is an operation description diagram showing a state in which the clamshell bucket has been lifted off the ground.

MODE FOR CARRYING OUT THE INVENTION

[0015] Hereinafter, the deep foundation excavation machine according to an embodiment of the present invention will be

described in detail with reference to FIGS. 1 to 10. In this embodiment, the travel direction of the deep foundation excavation machine is referred to as the longitudinal direction, and the direction orthogonal to this travel direction is referred to as the lateral direction.

[0016] In FIG. 1, the deep foundation excavation machine 1 comprises a self-propelled crawler-type lower travel body 2, an upper swing body 3 rotatably mounted on the lower travel body 2, and a work device 5 attached to the upper swing body 3, which will be described later. The lower travel body 2 and the upper swing body 3 constitute a vehicle body of the deep foundation excavation machine 1.

[0017] A cab 4 that defines an operator’s cab is provided on the left front side of the upper swing body 3. In the cab 4, an operator's seat (not shown) for operating the deep foundation excavation machine 1 is provided. Around the operator's seat, a raising-lowering operation device 32, an opening-closing operation device 34, and an operation switch 50, which will be described later, are provided.

[0018] The work device 5 comprises a boom 6, which is rotatably mounted on the upper swing body 3, an arm 7, which is rotatably mounted at a distal end of the boom 6, a clamshell bucket 10, which will be described later, and a bucket raising-lowering and opening-closing device 11. Between the upper swing body 3 and the boom 6, there is a boom cylinder 8 configured to rotate the boom 6 relative to the upper swing body 3. Between the boom 6 and the arm 7, there is an arm cylinder 9 configured to rotate the arm 7 relative to the boom 6.

[0019] The arm 7 is formed, for example, as an elongated square tubular body. On the outer peripheral surface of the arm 7, a bucket raising-lowering and opening-closing device 11 is mounted. At a distal end of the arm 7, a raising-lowering guide sheave 22 for guiding a raising-lowering rope 24 downwardly and an opening-closing guide sheave 23 for guiding an opening-closing rope 25 downwardly, which will be described later, are provided (see FIG. 2).

[0020] The clamshell bucket 10 includes a bucket support portion 10A, a pair of buckets 10B attached so as to be openable and closable under the bucket support portion 10A, a connection bracket 10C, and a pair of opening-closing arms 10D. The pair of buckets 10B are rotatably connected to the connection bracket 10C. The pair of opening-closing arms 10D connect the bucket support portion 10A and the pair of buckets 10B. On the bucket support portion 10A, a plurality of upper sheaves 10E are provided. On the connection bracket 10C, a plurality of lower sheaves 10F are provided so as to face the upper sheaves 10E in the vertical direction.

[0021] At the bucket support portion 10A of the clamshell bucket 10, the other end 24B of the raising-lowering rope 24 is attached. Additionally, the opening-closing rope 25 is alternately wound around the upper sheaves 10E and the lower sheaves 10F of the clamshell bucket 10. The other end 25B of the opening-closing rope 25 is attached to the bucket support portion 10A of the clamshell bucket 10.

[0022] The bucket raising-lowering and opening-closing device 11 is provided on the arm 7. The bucket raising-lowering and

opening-closing device 11 performs operations such as raising-lowering and opening-closing of the clamshell bucket 10. As shown in FIG. 2, the bucket raising-lowering and opening-closing device 11 includes a raising-lowering cylinder 12, a first raising-lowering sheave 14, a first opening-closing sheave 15, a second raising-lowering sheave 17, an opening-closing cylinder 18, a second opening-closing sheave 20, a raising-lowering rope 24, and an opening-closing rope 25.

[0023] The raising-lowering cylinder 12 is provided along the longitudinal direction of the arm 7. The raising-lowering cylinder 12 extends or contracts in response to operation of the raising-lowering operation device 32 to raise or lower the clamshell bucket 10. The raising-lowering cylinder 12 includes a tube 12A with its base end attached to the arm 7, a piston 12B inserted within the tube 12A, and a rod 12C with one end attached to the piston 12B and the other end extendably protruding from the tube 12A.

[0024] The first shaft member 13 is connected to the tip of the rod 12C of the raising-lowering cylinder 12. The first shaft member 13 extends in a lateral direction (width direction) intersecting with the extension-contraction direction of the raising-lowering cylinder 12, i.e., the longitudinal direction of the arm 7, and rotatably supports the first raising-lowering sheave 14 and the first opening-closing sheave 15.

[0025] The first raising-lowering sheave 14 is attached via the first shaft member 13 to the tip of the rod 12C, which is at one end side of the raising-lowering cylinder 12. The first raising-lowering sheave 14 is provided as a plurality of sheaves

(with 2 sheaves exemplified in FIG. 2) in a laterally overlapping manner on the first shaft member 13, and is movable in the extension-contraction direction (longitudinal direction of the arm 7) of the raising-lowering cylinder 12. The number of first raising-lowering sheaves 14 is set according to the required vertical excavation depth.

[0026] The first opening-closing sheave 15 is mounted together with the first raising-lowering sheave 14 to the tip of the rod 12C, which is at one end side of the raising-lowering cylinder 12, via the first shaft member 13. The first opening-closing sheave 15 is provided as a plurality of sheaves (with 2 sheaves exemplified in FIG. 2) in a laterally overlapping manner on the first shaft member 13, and is movable in the extension-contraction direction of the raising-lowering cylinder 12. Therefore, these first opening-closing sheaves 15 and the first raising-lowering sheaves 14 move integrally in the length direction of the arm 7 due to the extension-contraction operation of the raising-lowering cylinder 12.

[0027] The second shaft member 16 is fixedly attached to a distal side of the arm 7, where a raising-lowering guide sheave 22 and an opening-closing guide sheave 23 are provided. The second shaft member 16 extends in a direction (lateral direction) intersecting with the extension-contraction direction of the raising-lowering cylinder 12 and rotatably supports the second raising-lowering sheave 17.

[0028] The second raising-lowering sheave 17 is rotatably supported by the second shaft member 16 in a state spaced from the plurality of first raising-lowering sheaves 14 in the

extension-contraction direction of the raising-lowering cylinder 12 (with one sheave exemplified in FIG. 2). The second raising-lowering sheave 17 is fixed in the extension-contraction direction of the raising-lowering cylinder 12 relative to the arm 7. Therefore, the first raising-lowering sheave 14 approaches or moves away from the second raising-lowering sheave 17 according to the extension-contraction operation of the raising-lowering cylinder 12.

[0029] The opening-closing cylinder 18 is provided on the arm 7 in parallel with the raising-lowering cylinder 12 and extends in the length direction of the arm 7. The opening-closing cylinder 18 extends or contracts in response to operation of the opening-closing operation device 34 to open or close the clamshell bucket 10. The opening-closing cylinder 18 includes a tube 18A with its base end attached to the arm 7, a piston 18B inserted into the tube 18A, and a rod 18C with one end attached to the piston 18B and the other end extendably protruding from the tube 18A.

[0030] The third shaft member 19 is provided at the tip end of the rod 18C of the opening-closing cylinder 18. The third shaft member 19 extends in a lateral direction intersecting with the extension-contraction direction of the raising-lowering cylinder 12, i.e., the longitudinal direction of the arm 7, and rotatably supports the second opening-closing sheave 20.

[0031] The second opening-closing sheave 20 is rotatably supported by the third shaft member 19 in a state spaced from the plurality of first opening-closing sheaves 15 in the extension-contraction direction of the raising-lowering cylinder 12. In FIG. 2, only one second opening-closing sheave 20 is illustrated for clarity,

but a plurality of second opening-closing sheaves 20 are provided on the third shaft member 19. The second opening-closing sheave 20 is movable in the extension-contraction direction of the opening-closing cylinder 18. The opening-closing cylinder 18 causes the second opening-closing sheave 20 to move in the length direction of the arm 7 according to its extension-contraction operation, so that the second opening-closing sheave 20 approaches or moves away from the first opening-closing sheave 15.

[0032] Here, the stroke length Sc of the opening-closing cylinder 18 is set to a value equal to or greater than a sum obtained by adding a stroke length Xb required for opening and closing the clamshell bucket 10 during excavation work (transitioning from a state shown in FIG. 7 to a state shown in FIG. 8), and a stroke length Xs required to remove the loosening of the opening-closing rope 25 when the clamshell bucket 10 lands on the excavation site (ground) (transitioning from a state shown in FIG. 6 to a state shown in FIG. 7). The stroke length Sc is expressed by the following Equation 1.

[0033] [Equation 1]

$$Sc \geqq Xb + Xs$$

[0034] In this case, if the amount of movement of the lower sheave 10F relative to the upper sheave 10E during opening and closing of the clamshell bucket 10 is Sb, the number of windings of the opening-closing rope 25 around the upper sheave 10E and the lower sheave 10F is Nb, and the number of windings of the opening-closing rope 25 around the second opening-closing sheave 20 is Nc, the stroke length required for opening and closing the clamshell bucket 10, i.e., the stroke length Xb corresponding to the opening-closing

range of the clamshell bucket 10, is expressed by the following equation 2.

[0035] [Equation 2]

$$Xb = \frac{Sb \times Nb}{Nc}$$

[0036] In addition, if the loosening amount of the opening-closing rope 25 when the clamshell bucket 10 lands at an excavation location (ground) is x, and Nc is the number of windings of the opening-closing rope 25 around the second opening-closing sheave 20, the stroke length required to remove the loosening of the opening-closing rope 25 when the clamshell bucket 10 lands at the excavation location (ground), that is, the stroke length Xs corresponding to the loosening amount of the opening-closing rope 25 that occurs from when the clamshell bucket 10 lands on the ground until the raising-lowering cylinder 12 stops, is expressed by the following Equation 3.

[0037] [Equation 3]

$$Xs = \frac{x}{Nc}$$

[0038] Thus, the stroke length Sc of the opening-closing cylinder 18 according to the embodiment is set to a value equal to or greater than a sum obtained by adding a stroke length Xb required for opening and closing the clamshell bucket 10 and a stroke length Xs required to remove the loosening of the opening-closing rope 25 that occurs when the clamshell bucket 10 lands at the excavation site. This eliminates the need for a dedicated device to remove the loosening of the opening-closing rope 25 such as a loosening removal cylinder used in the prior art and, as will be described

later, allows the loosening of the opening-closing rope 25 to be removed using the opening-closing cylinder 18, enabling the clamshell bucket 10 to be closed quickly.

[0039] The fourth shaft member 21 is attached at a distal end of the arm 7. The fourth shaft member 21 extends in the lateral direction intersecting with the extension-contraction direction of the raising-lowering cylinder 12, that is, the longitudinal direction of the arm 7, and rotatably supports the raising-lowering guide sheave 22 and the opening-closing guide sheave 23.

[0040] The raising-lowering guide sheave 22 and the opening-closing guide sheave 23 are attached at a distal end of the arm 7 via the fourth shaft member 21 and are rotatably supported by the fourth shaft member 21. The raising-lowering guide sheave 22 guides the raising-lowering rope 24 from the arm 7 toward the clamshell bucket 10. On the other hand, the opening-closing guide sheave 23 guides the opening-closing rope 25 from the arm 7 toward the clamshell bucket 10.

[0041] The raising-lowering rope 24 is provided between the arm 7 and the clamshell bucket 10, so as to support the clamshell bucket 10 to be raisable and lowerable. The raising-lowering rope 24 is made of wire rope, and one end 24A in the length direction is attached to the arm 7. The other end 24B of the raising-lowering rope 24 extends downward from the raising-lowering guide sheave 22 and is attached to the bucket support portion 10A of the clamshell bucket 10. The intermediate portion 24C of the raising-lowering rope 24 is alternately wound around the first raising-lowering sheave 14 and the second raising-lowering sheave 17.

[0042] The opening-closing rope 25 is provided between the arm 7 and the clamshell bucket 10, allowing a pair of buckets 10B of the clamshell bucket 10 to be opened and closed. The opening-closing rope 25 is made of wire rope, and one end 25A in the length direction is attached to the arm 7. The other end 25B of the opening-closing rope 25 extends downward from the opening-closing guide sheave 23 and is attached to the bucket support portion 10A of the clamshell bucket 10. The intermediate portion 25C of the opening-closing rope 25 is alternately wound around the first opening-closing sheave 15 and the second opening-closing sheave 20. Additionally, the other end 25B side of the opening-closing rope 25 is alternately wound around the upper sheave 10E and the lower sheave 10F of the clamshell bucket 10.

[0043] Accordingly, the clamshell bucket 10 lowers when the raising-lowering cylinder 12 contracts, causing the first raising-lowering sheave 14 to approach the second raising-lowering sheave 17. Additionally, the clamshell bucket 10 rises when the raising-lowering cylinder 12 extends, causing the first raising-lowering sheave 14 to move away from the second raising-lowering sheave 17. In this case, by increasing the number of the first raising-lowering sheaves 14 and the second raising-lowering sheaves 17, or by changing the stroke of the raising-lowering cylinder 12, the lowering distance (maximum depth) of the clamshell bucket 10 can be freely set.

[0044] On the other hand, the clamshell bucket 10 opens as the opening-closing cylinder 18 contracts and the second opening-closing sheave 20 approaches the first opening-closing

sheave 15 (see FIG. 4). Additionally, the clamshell bucket 10 closes as the opening-closing cylinder 18 extends, causing the second opening-closing sheave 20 to move away from the first opening-closing sheave 15 (see FIG. 8).

[0045] Next, a hydraulic circuit for driving the raising-lowering cylinder 12 and the opening-closing cylinder 18 constituting the bucket raising-lowering and opening-closing device 11 will be described with reference to FIG. 3.

[0046] A hydraulic pump 26, together with a tank 27, constitutes a hydraulic power source. The hydraulic pump 26 is driven by the engine (prime mover) mounted on the deep foundation excavation machine 1. A pilot pump 28 is connected to the hydraulic pump 26, and the pilot pump 28 is driven by the engine along with the hydraulic pump 26. Hydraulic fluid (pressurized oil) discharged from the hydraulic pump 26 is supplied to the raising-lowering cylinder 12 and the opening-closing cylinder 18 via the center bypass-type main line 29. The main line 29 includes a raising-lowering pump line 29A for supplying hydraulic fluid from the hydraulic pump 26 to the raising-lowering cylinder 12, an opening-closing pump line 29B for supplying hydraulic fluid from the hydraulic pump 26 to the opening-closing cylinder 18, and a tank line 29C connected to the tank 27.

[0047] A raising-lowering switching valve 30 is provided between the hydraulic pump 26 and the raising-lowering cylinder 12. The raising-lowering switching valve 30 is configured, for example, as a hydraulic pilot type directional control valve with 6 ports and 3 positions. The raising-lowering switching valve 30 is connected to the rod side oil chamber 12D of the raising-lowering

cylinder 12 via the rod side line 30A, and to the bottom-side oil chamber 12E of the raising-lowering cylinder 12 via the bottom-side line 30B. By switching the raising-lowering switching valve 30 from the neutral position to position (a), the hydraulic fluid from the hydraulic pump 26 is supplied to the rod side oil chamber 12D of the raising-lowering cylinder 12 through the rod side line 30A. As a result, the raising-lowering cylinder 12 contracts, and the clamshell bucket 10 lowers. On the other hand, by switching the raising-lowering switching valve 30 from the neutral position to position (b), the hydraulic fluid from the hydraulic pump 26 is supplied to the bottom-side oil chamber 12E of the raising-lowering cylinder 12 through the bottom-side line 30B. As a result, the raising-lowering cylinder 12 extends, and the clamshell bucket 10 rises.

[0048] An opening-closing switching valve 31 is provided between the hydraulic pump 26 and the opening-closing cylinder 18. The opening-closing switching valve 31 is configured, for example, as a hydraulic pilot type directional control valve with 6 ports and 3 positions. The opening-closing switching valve 31 is connected to the rod side oil chamber 18D of the opening-closing cylinder 18 via the rod side line 31A, and to the bottom-side oil chamber 18E of the opening-closing cylinder 18 via the bottom-side line 31B. The opening-closing switching valve 31 is switched from the neutral position to position (c), thereby supplying hydraulic fluid from the hydraulic pump 26 to the rod side oil chamber 18D of the opening-closing cylinder 18 via the rod side line 31A. This causes the opening-closing cylinder 18 to contract, opening the clamshell bucket 10. On the other hand, by switching the

opening-closing switching valve 31 from the neutral position to position (d), the hydraulic fluid from the hydraulic pump 26 is supplied to the bottom-side oil chamber 18E of the opening-closing cylinder 18 through the bottom-side line 31B. This causes the opening-closing cylinder 18 to extend, closing the clamshell bucket 10.

[0049] A raising-lowering operation device 32 and an opening-closing operation device 34 are provided inside the cab 4 of the deep foundation excavation machine 1. The raising-lowering operation device 32 is configured as a pressure-reducing valve type pilot-operated valve, including a contraction side pressure reducing valve portion 32A and an extension side pressure reducing valve portion 32B, and includes a pedal 32C operated by the operator. When the pedal 32C of the raising-lowering operation device 32 is operated to the contraction side, the pilot pressure discharged from a pilot pump 28 is supplied to the raising-lowering switching valve 30 through the contraction side pressure reducing valve portion 32A via a pilot line 33A. This switches the raising-lowering switching valve 30 to position (a), causing the raising-lowering cylinder 12 to contract and the clamshell bucket 10 to lower. On the other hand, when the pedal 32C of the raising-lowering operation device 32 is operated to the extension side, pilot pressure is supplied to the raising-lowering switching valve 30 from the extension side pressure reducing valve portion 32B via a pilot line 33B. This switches the raising-lowering switching valve 30 to position (b), causing the raising-lowering cylinder 12 to extend and the clamshell bucket 10 to rise.

[0050] The opening-closing operation device 34 is configured as

a pressure-reducing valve type pilot-operated valve, including a contraction side pressure reducing valve portion 34A and an extension side pressure reducing valve portion 34B, and includes a lever 34C operated by the operator. When the lever 34C of the opening-closing operation device 34 is operated to the contraction side, the pilot pressure discharged from the pilot pump 28 is supplied to the opening-closing switching valve 31 through the contraction side pressure reducing valve portion 34A via a pilot line 35A. This switches the opening-closing switching valve 31 to position (c), causing the opening-closing cylinder 18 to contract and the clamshell bucket 10 to open. On the other hand, when the lever 34C of the opening-closing operation device 34 is operated to the extension side, pilot pressure is supplied to the opening-closing switching valve 31 from the extension side pressure reducing valve portion 34B via a pilot line 35B. This switches the opening-closing switching valve 31 to position (d), causing the opening-closing cylinder 18 to extend and the clamshell bucket 10 to close.

[0051] A loosening detection device 36 is provided between the arm 7 and one end 24A of the raising-lowering rope 24 (see FIG. 2). The loosening detection device 36 comprises a spring member 36A and a detector 36B. The spring member 36A is formed of a compression spring sandwiched between the arm 7 and one end 24A of the raising-lowering rope 24. When the clamshell bucket 10 is supported by the raising-lowering rope 24, the spring member 36A is contracted by the weight of the clamshell bucket 10, and remains out of contact with the detector 36B (see FIG. 4). On the other hand, when the clamshell bucket 10 lands and the raising-lowering

rope 24 becomes loosened, the spring member 36A extends as the weight of the clamshell bucket 10 is relieved, contacting the detector 36B (see FIG. 6).

[0052] The detector 36B detects the loosening of the raising-lowering rope 24 that occurs when the clamshell bucket 10 lands. The detector 36B is formed by a contact type sensor (switch) that switches between ON and OFF states depending on the contact and non-contact states of the spring member 36A. When the detector 36B is in the ON state, a relay 36C is energized. When the spring member 36A is contracted by the weight of the clamshell bucket 10 and is out of contact with the detector 36B, the detector 36B is in an OFF state. On the other hand, when the clamshell bucket 10 lands and the raising-lowering rope 24 is loosened, causing the spring member 36A to contact the detector 36B, the detector 36B switches from the OFF state to the ON state. This causes the relay 36C to be energized, and an electric power (loosening detection signal) is supplied from a battery 37 to an electromagnetic pilot portion 40A of a lowering stop valve 40, which will be described later. At the same time, the electric power from the battery 37 is also supplied to a notification lamp 38 and a buzzer 39 installed in the cab 4, causing the notification lamp 38 to light up and the buzzer 39 to sound. This allows the operator inside the cab 4 to recognize the loosened state of the raising-lowering rope 24 by the notification lamp 38 and the buzzer 39.

[0053] The lowering stop valve 40 is provided along the pilot line 33A connected to the contraction side pressure reducing valve portion 32A of the raising-lowering operation device 32. The

lowering stop valve 40 is configured as a directional control valve with 3 ports and 2 positions with an electromagnetic pilot portion 40A, which is held at position (e) when no electric power is supplied and is switched to position (f) when electric power is supplied. When the lowering stop valve 40 is at position (e), pilot pressure is supplied to the raising-lowering switching valve 30 through the pilot line 33A. When the lowering stop valve 40 is at position (f), the pilot line 33A is cut off, and the hydraulic fluid (pilot pressure) that was supplied to the raising-lowering switching valve 30 is returned to the tank 27 through the return line 41.

[0054] A variable throttle valve 42 is provided on the return line 41. The variable throttle valve 42 forms additional loosening in the raising-lowering rope 24 and the opening-closing rope 25 to allow the clamshell bucket 10 to dig into the ground when it lands. Specifically, the variable throttle valve 42 restricts the flow rate of hydraulic fluid returned to the tank 27 from the pilot line 33A through the return line 41 when the raising-lowering switching valve 30 switches to the neutral position. Therefore, there is a time delay caused by the variable throttle valve 42 from when the clamshell bucket 10 lands until the actual stopping of the contraction motion of the raising-lowering cylinder 12 (pay-out of the raising-lowering rope 24 and opening-closing rope 25). This forms additional loosening in the raising-lowering rope 24 and the opening-closing rope 25, allowing the clamshell bucket 10 to be dug into the ground.

[0055] An emergency lowering valve 43 is connected to the pilot line 33A so as to bypass the lowering stop valve 40 (in a parallel

state). The emergency lowering valve 43 is configured as a manually operated normally closed valve with 2 ports and 2 positions and a switching lever 43A and is normally held at a closed position (g) and is switched to an open position (h) by operating the switching lever 43A. When the emergency lowering valve 43 is in the open position (h), the pilot pressure flowing through the pilot line 33A bypasses the lowering stop valve 40 and is supplied to the raising-lowering switching valve 30. Therefore, even if the pilot pressure from the raising-lowering operation device 32 cannot be supplied to the raising-lowering switching valve 30 due to a malfunction of the lowering stop valve 40, preventing the clamshell bucket 10 from lowering, the clamshell bucket 10 can be lowered by operating the switching lever 43A of the emergency lowering valve 43.

[0056] A raising-lowering cylinder relief valve 44 is connected to the bottom-side line 30B connected to the bottom-side oil chamber 12E of the raising-lowering cylinder 12 and the tank line 29C. The raising-lowering cylinder relief valve 44 relieves excess pressure to the tank 27 through the tank line 29C when pressure exceeding the preset relief pressure (excess pressure) occurs in the bottom-side oil chamber 12E of the raising-lowering cylinder 12.

[0057] An opening-closing cylinder relief valve 45 is connected to the bottom-side line 31B connected to the bottom-side oil chamber 18E of the opening-closing cylinder 18 and the tank line 29C. The opening-closing cylinder relief valve 45 relieves excess pressure to the tank 27 through the tank line 29C when pressure exceeding a preset relief pressure (excess pressure) occurs in

the bottom-side oil chamber 18E of the opening-closing cylinder 18. The opening-closing cylinder relief valve 45 relieves excess pressure to the tank 27 when, during excavation work to be described later, the weight of the clamshell bucket 10 acts on the opening-closing rope 25 and causes excess pressure to occur in the bottom-side oil chamber 18E of the opening-closing cylinder 18.

[0058] Here, a relief pressure Pr of the raising-lowering cylinder relief valve 44 and a relief pressure Pc of the opening-closing cylinder relief valve 45 are set to meet the following conditions 1 to 3 during the excavation work to be described later.

[0059] Condition 1: By extending the opening-closing cylinder 18 to close the clamshell bucket 10, earth and sand are excavated. However, even if the extension operation of the opening-closing cylinder 18 is continued after closing the clamshell bucket 10, the clamshell bucket 10 cannot be raised (lifted) solely by the opening-closing rope 25.

[0060] Specifically, let Fb be the tension of the opening-closing rope 25 necessary for the clamshell bucket 10 to excavate earth and sand, Nb be the number of windings of the opening-closing rope 25 around the upper sheave 10E and the lower sheave 10F, Ac be the pressure-receiving area of the bottom-side oil chamber 18E of the opening-closing cylinder 18, Nc be the number of windings of the opening-closing rope 25 around the second opening-closing sheave 20, and W1 be the sum of the self-weight of the clamshell bucket 10 and the weight of the opening-closing rope 25 acting on the clamshell bucket 10 (weight of the portion from the other end 25B of the opening-closing rope 25 to the opening-closing guide

sheave 23). Condition 1 is expressed by the following Equation 4.

[0061] [Equation 4]

$$\frac{Fb}{Nb} < \frac{Pc \times Ac}{Nc} < W1$$

[0062] Condition 2: By extending the raising-lowering cylinder 12, the clamshell bucket 10 can be raised (lifted) using the raising-lowering rope 24 and the opening-closing rope 25.

[0063] Specifically, let W2 be the sum of the self-weight of the clamshell bucket 10, the weight of the opening-closing rope 25 acting on the clamshell bucket 10 (weight of the portion of the opening-closing rope 25 from the other end 25B to the opening-closing guide sheave 23), the weight of the raising-lowering rope 24 acting on the clamshell bucket 10 (weight of the portion of the raising-lowering rope 24 from the other end 24B to the raising-lowering guide sheave 22), and the weight of the maximum load of earth and sand that can be excavated by the clamshell bucket 10. Also, let Ar be the pressure-receiving area of the bottom-side oil chamber 12E of the raising-lowering cylinder 12, and let Nr be the number of windings of the raising-lowering rope 24 around the first raising-lowering sheave 14. Condition 2 is expressed by the following equation 5.

[0064] [Equation 5]

$$W2 < \frac{Pr \times Ar}{Nr}$$

[0065] Condition 3: When the raising-lowering rope 24 is loosened while the clamshell bucket 10 is in a closed state, the raising-lowering cylinder 12 is extended to remove the loosening

of the raising-lowering rope 24, and any excess pressure generated in the bottom-side oil chamber 18E of the opening-closing cylinder 18 can be relieved by the opening-closing cylinder relief valve 45, thereby allowing the opening-closing cylinder 18 to contract.

[0066] Specifically, let Ac be the pressure-receiving area of the bottom-side oil chamber 18E of the opening-closing cylinder 18, Nc be the number of windings of the opening-closing rope 25 around the second opening-closing sheave 20, Ar be the pressure-receiving area of the bottom-side oil chamber 12E of the raising-lowering cylinder 12, and Nr be the number of windings of the raising-lowering rope 24 around the first raising-lowering sheave 14. Condition 3 is expressed by the following equation 6.

[0067] [Equation 6]

$$\frac{Pc \times Ac}{Nc} < \frac{Pr \times Ar}{Nr}$$

[0068] When Equations 4, 5, and 6 are combined, the relief pressure Pr of the raising-lowering cylinder relief valve 44 and the relief pressure Pc of the opening-closing cylinder relief valve 45 are set to satisfy the following equation 7.

[0069] [Equation 7]

$$\frac{Fb}{Nb} < \frac{Pc \times Ac}{Nc} < W1 < W2 < \frac{Pr \times Ar}{Nr}$$

[0070] In this way, in this embodiment, excess pressure generated in the bottom-side oil chamber 18E of the opening-closing cylinder 18 is relieved to the tank 27 by the opening-closing cylinder relief valve 45. As a result, the clamshell bucket 10 that excavates earth and sand, can be stably lifted by the raising-lowering rope 24 and the opening-closing rope 25 without being lifted solely by

the opening-closing rope 25.

[0071] The second hydraulic pump 46 is connected in parallel to the hydraulic pump 26 with respect to the main line 29. Specifically, the second hydraulic pump 46 is connected to a branch line 29D branching from a raising-lowering pump line 29A, and is driven by the engine together with the hydraulic pump 26 to discharge hydraulic fluid to the raising-lowering pump line 29A via the branch line 29D.

[0072] A confluence switching valve 47 is positioned between the second hydraulic pump 46 and the raising-lowering switching valve 30 and is provided on the branch line 29D. The confluence switching valve 47 is configured as a hydraulic pilot type opening-closing valve with 2 ports and 2 positions, and is normally held at a closed valve position (j) to cut off the branch line 29D. On the other hand, the confluence switching valve 47 is switched to an open valve position (k) to open the branch line 29D by supply of pilot pressure from the extension side pressure reducing valve portion 32B when the raising-lowering operation device 32 is operated to the extension side.

[0073] Therefore, when the raising-lowering operation device 32 is operated to the contraction side to lower the clamshell bucket 10, only the hydraulic fluid discharged from the hydraulic pump 26 is supplied to the rod side oil chamber 12D of the raising-lowering cylinder 12 via the raising-lowering switching valve 30. On the other hand, when the raising-lowering operation device 32 is operated to the extension side to raise the clamshell bucket 10, the hydraulic fluid discharged from the hydraulic pump 26 and the hydraulic fluid discharged from the second hydraulic

pump 46 merge in the raising-lowering pump line 29A and are supplied to the bottom-side oil chamber 12E of the raising-lowering cylinder 12 via the raising-lowering switching valve 30. In this way, the second hydraulic pump 46 and the confluence switching valve 47 constitute a raising-lowering flow rate adjustment device that varies the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12 when raising and lowering the clamshell bucket 10.

[0074] A raising pressure reducing valve 48 is provided on the pilot line 33B connecting the extension side pressure reducing valve portion 32B of the raising-lowering operation device 32 and the raising-lowering switching valve 30. The raising pressure reducing valve 48 is provided with an electromagnetic pilot portion 48A, and electric power (speed switching signal) is supplied to the electromagnetic pilot portion 48A according to the operation of an operation switch 50 described later. The raising pressure reducing valve 48 is a variable pressure reducing valve that can adjust the set pressure (degree of pressure reduction). When the operation switch 50 is turned OFF, the supply of electric power to the electromagnetic pilot portion 48A is stopped, and the pilot pressure flowing through the pilot line 33B is supplied to the raising-lowering switching valve 30 in a pressure-reduced state by the raising pressure reducing valve 48. On the other hand, when the operation switch 50 is turned ON, electric power is supplied to the electromagnetic pilot portion 48A, and the pilot pressure flowing through the pilot line 33B is supplied to the raising-lowering switching valve 30 while bypassing the raising pressure reducing valve 48.

[0075] The lowering pressure reducing valve 49 is provided on the pilot line 33A connecting the contraction side pressure reducing valve portion 32A of the raising-lowering operation device 32 and the raising-lowering switching valve 30. The lowering pressure reducing valve 49 has an electromagnetic pilot portion 49A, and electric power (speed switching signal) is supplied to the electromagnetic pilot portion 49A according to the operation of the operation switch 50. The lowering pressure reducing valve 49 is a variable pressure reducing valve that can adjust the set pressure. When the operation switch 50 is turned OFF, the supply of electric power to the electromagnetic pilot portion 49A is stopped, and the pilot pressure flowing through the pilot line 33A is supplied to the raising-lowering switching valve 30 in a pressure-reduced state by the lowering pressure reducing valve 49. On the other hand, when the operation switch 50 is turned ON, electric power is supplied to the electromagnetic pilot portion 49A, and the pilot pressure flowing through the pilot line 33A is supplied to the raising-lowering switching valve 30 while bypassing the lowering pressure reducing valve 49.

[0076] The operation switch 50 is positioned inside the cab 4 and operated to turn ON and OFF by the operator. The operation switch 50 is electrically connected between the battery 51 and the relay 52, and when the operation switch 50 is turned ON, the relay 52 is energized. As a result, electric power (speed switching signal) from the battery 51 is supplied to the electromagnetic pilot portion 48A of the raising pressure reducing valve 48 and the electromagnetic pilot portion 49A of the lowering pressure reducing valve 49. Therefore, when the operation switch 50 is

turned ON by the operator, the pilot pressure output from the extension side pressure reducing valve portion 32B of the raising-lowering operation device 32 is supplied to the raising-lowering switching valve 30 while bypassing the raising pressure reducing valve 48, and pilot pressure output from the contraction side pressure reducing valve portion 32A is supplied to the raising-lowering switching valve 30 while bypassing the lowering pressure reducing valve 49.

[0077] When the operation switch 50 is turned OFF, the extension-contraction speed of the raising-lowering cylinder 12 is limited by the raising pressure reducing valve 48 and the lowering pressure reducing valve 49, thereby controlling the raising-lowering speed of the clamshell bucket 10. On the other hand, when the operation switch 50 is turned ON, the limitation on the extension-contraction speed of the raising-lowering cylinder 12 is released, allowing the raising-lowering speed of the clamshell bucket 10 to increase. Additionally, when the operation switch 50 is turned ON, electric power from the battery 51 is supplied to a notification lamp 53 located inside the cab 4, causing the notification lamp 53 to light up. As a result, the operator inside the cab 4 can confirm the increase in the raising-lowering speed of the clamshell bucket 10 through the notification lamp 53. In this manner, the raising pressure reducing valve 48 and the lowering pressure reducing valve 49 constitute a raising-lowering speed adjustment device that adjusts the speed (raising-lowering speed of the clamshell bucket 10) at which the clamshell bucket 10 is raised and lowered.

[0078] A bucket opening pressure reducing valve 54, serving as

the bucket flow rate adjustment device, is provided in the pilot line 35A connecting the contraction side pressure reducing valve portion 34A of the opening-closing operation device 34 and the opening-closing switching valve 31. The bucket opening pressure reducing valve 54 is a variable pressure reducing valve that can adjust the set pressure (degree of pressure reduction) and is adjusted, for example, to a set pressure that allows the speed of contraction of the opening-closing cylinder 18 to approach the moving speed of the opening-closing rope 25 when the clamshell bucket 10 opens. This allows the opening-closing cylinder 18 to contract according to the moving speed of the opening-closing rope 25, enabling the clamshell bucket 10 to open without loosening the opening-closing rope 25.

[0079] The deep foundation excavation machine 1 according to the embodiment has the aforementioned configuration, and the operations for excavating a vertical shaft using the deep foundation excavation machine 1 will be described below.

[0080] The operator inside the cab 4 places the clamshell bucket 10 in a closed state above the ground where the vertical shaft is to be excavated. At this time, the spring member 36A of the loosening detection device 36 is contracted by the weight of the clamshell bucket 10 and is out of contact with the detector 36B, which is in the OFF state. In this state, the operator operates the raising-lowering operation device 32 toward the contraction side. As a result, the pilot pressure is supplied to the raising-lowering switching valve 30 through the pilot line 33A, and the raising-lowering cylinder 12 contracts. Thus, as the first raising-lowering sheave 14 approaches the second raising-lowering

sheave 17 and the first opening-closing sheave 15 approaches the second opening-closing sheave 20, the raising-lowering rope 24 and the opening-closing rope 25 are fed from the arm 7, causing the clamshell bucket 10 to lower.

[0081] Here, in this embodiment, the operation switch 50 is provided in the cab 4, and when the operation switch 50 is turned ON by the operator, electric power is supplied to the electromagnetic pilot portion 49A of the lowering pressure reducing valve 49 installed in the pilot line 33A. As a result, the pilot pressure flowing through the pilot line 33A is supplied to the raising-lowering switching valve 30 while bypassing the lowering pressure reducing valve 49. This allows the raising-lowering cylinder 12 to contract according to the contraction side operation on the raising-lowering operation device 32, enabling the clamshell bucket 10 to lower quickly.

[0082] When the clamshell bucket 10 lowers and reaches a position a few meters (e.g., 2-3 meters) above the ground, the operator stops the operation of the raising-lowering operation device 32 to temporarily halt the lowering operation of the clamshell bucket 10. Additionally, the operator operates the opening-closing operation device 34 toward the contraction side. This causes the opening-closing cylinder 18 to contract, bringing the second opening-closing sheave 20 to approach the first opening-closing sheave 15. As a result, the opening-closing rope 25 is fed from the arm 7, and as shown in FIG. 4, the clamshell bucket 10 fully opens. Here, when the clamshell bucket 10 is opened, the protruding length of the rod 18C from the tube 18A of the opening-closing cylinder 18 is defined as the initial protruding length L.

[0083] In this manner, after the clamshell bucket 10 is fully opened, the operator stops the operation of the opening-closing operation device 34 and operates the raising-lowering operation device 32 toward the contraction side. As a result, the fully opened clamshell bucket 10 lowers, and the lower ends of the pair of buckets 10B land on the ground (see FIG. 5).

[0084] After the clamshell bucket 10 lands, the operator continues to operate the raising-lowering operation device 32 toward the contraction side. This causes the raising-lowering rope 24 and the opening-closing rope 25 to be further fed while maintaining the position of the clamshell bucket 10, allowing the raising-lowering rope 24 and the opening-closing rope 25 to become loosened (see FIG. 6). Thus, after the clamshell bucket 10 lands, the loosening of the raising-lowering rope 24 and the opening-closing rope 25 allows the clamshell bucket 10 to dig into the ground by its own weight.

[0085] At this time, the loosening of the raising-lowering rope 24 causes the spring member 36A of the loosening detection device 36 to extend and come into contact with the detector 36B, switching the detector 36B to the ON state. This supplies electric power (loosening detection signal) from the battery 37 to the electromagnetic pilot portion 40A of the lowering stop valve 40, the notification lamp 38, and the buzzer 39. Thus, the lowering stop valve 40 switches to position (f), thereby cutting off the pilot pressure supply to the raising-lowering switching valve 30, stopping the lowering operation of the clamshell bucket 10. The operator recognizes that the clamshell bucket 10 has landed through the lighting of the notification lamp 38 and the sounding of the

buzzer 39, and stops operation of the raising-lowering operation device 32.

[0086] Here, the hydraulic fluid returning to the tank 27 from the raising-lowering switching valve 30 is flow-restricted by the variable throttle valve 42 installed in the return line 41, requiring time for the raising-lowering switching valve 30 to switch from position (a) to a neutral position. This allows for the formation of additional loosening in the raising-lowering rope 24 and the opening-closing rope 25 between the time the clamshell bucket 10 lands and the contraction operation of the raising-lowering cylinder 12 stops.

[0087] Next, the operator operates the opening-closing operation device 34 toward the extension side. This supplies pilot pressure to the opening-closing switching valve 31 through the pilot line 35B, causing the opening-closing switching valve 31 to switch to position (d). As a result, the opening-closing cylinder 18 extends, causing the second opening-closing sheave 20 to move away from the first opening-closing sheave 15, resulting in the raising of the opening-closing rope 25. As a result, while the raising-lowering rope 24 remains loosened, only the loosening of the opening-closing rope 25 is removed (see FIG. 7). At this point, the protruding length of the rod 18C of the opening-closing cylinder 18 is the initial protruding length L when the clamshell bucket 10 is opened plus the stroke length Xs required to remove the loosening of the opening-closing rope 25. Thus, in this embodiment, by using the opening-closing cylinder 18 to remove the loosening of the opening-closing rope 25, it is possible to eliminate cumbersome tasks such as operating a dedicated device

for removing the loosening of the opening-closing rope 25, such as a loosening removal cylinder in the conventional art, thereby enhancing the efficiency of excavation work.

[0088] After the loosening of the opening-closing rope 25 is removed, the operator continues to operate the opening-closing operation device 34 toward the extension side. As a result, the opening-closing cylinder 18 further extends, causing the second opening-closing sheave 20 to move away from the first opening-closing sheave 15, leading to the raising of the opening-closing rope 25. As a result, the clamshell bucket 10 closes as it digs into the ground by its own weight, allowing it to scoop up a large amount of earth and sand (see FIG. 8). At this time, the protruding length of the rod 18C of the opening-closing cylinder 18 is the initial protruding length L when the clamshell bucket 10 is opened, plus the stroke length Xs required to remove the loosening of the opening-closing rope 25, and the stroke length Xb required to close the clamshell bucket 10. That is, as in the above equation 1, the stroke length Sc of the opening-closing cylinder 18 according to the embodiment is set to a value equal to or greater than a sum obtained by adding a stroke length Xs corresponding to the loosening amount of the opening-closing rope 25 that occurs after the clamshell bucket 10 lands and until the raising-lowering cylinder 12 stops, to a stroke length (i.e., the stroke length required to open and close the clamshell bucket 10) Xb corresponding to the opening-closing range of the clamshell bucket 10.

[0089] Here, at the preliminary stage before closing the clamshell bucket 10, the raising-lowering rope 24 remains loosened, while

only the loosening of the opening-closing rope 25 is removed. Accordingly, the opening-closing cylinder 18 can extend while simultaneously closing the clamshell bucket 10, thereby enhancing the efficiency of excavation work by rapidly excavating earth and sand. Moreover, the operation of removing the loosening of the opening-closing rope 25 and the operation of closing the clamshell bucket 10 to scoop earth and sand can be continuously performed by the extension operation of the opening-closing cylinder 18. For this reason, for example, compared to the case where the clamshell bucket 10 is closed using the opening-closing cylinder 18 after removing the loosening of the opening-closing rope 25 using a dedicated device such as a loosening removal cylinder, it is possible to eliminate the time lag between the removal of the loosening of the opening-closing rope 25 and the start of closing the clamshell bucket 10. Moreover, since the opening-closing rope 25 is often wrapped around the second opening-closing sheave 20 multiple times, it is possible to quickly remove the loosening of the opening-closing rope 25 compared to using dedicated devices such as a loosening removal cylinder. As a result, it is possible to improve the efficiency of excavation work and simplify the operator's operation.

[0090] After the clamshell bucket 10 is closed and the earth and sand are excavated, the operator operates the raising-lowering operation device 32 to the extension side. At this time, since the operation switch 50 is maintained in the ON state, electric power is supplied to the electromagnetic pilot portion 48A of the raising pressure reducing valve 48, and the pilot pressure from the extension side pressure reducing valve portion 32B is supplied

to the raising-lowering switching valve 30 while bypassing the raising pressure reducing valve 48. On the other hand, the confluence switching valve 47 switches to position (k) when pilot pressure is supplied through the pilot line 33B. As a result, the hydraulic fluid discharged from the hydraulic pump 26 and the hydraulic fluid discharged from the second hydraulic pump 46 merge in the raising-lowering pump line 29A and are supplied to the bottom-side oil chamber 12E of the raising-lowering cylinder 12 via the raising-lowering switching valve 30. As a result, the raising-lowering cylinder 12 extends, causing the first raising-lowering sheave 14 to move away from the second raising-lowering sheave 17, and the first opening-closing sheave 15 to move away from the second opening-closing sheave 20.

[0091] At this point, if loosening remains in the raising-lowering rope 24, the weight of the clamshell bucket 10 holding earth and sand acts only on the opening-closing rope 25, which may reduce the durability of the opening-closing rope 25. As such, when the weight of the clamshell bucket 10 acts on the opening-closing rope 25, a force acts in a direction causing the opening-closing cylinder 18 to contract, resulting in increased pressure within the bottom-side oil chamber 18E of the opening-closing cylinder 18.

[0092] In contrast, in this embodiment, the relief valve 45 for the opening-closing cylinder is connected between the bottom-side line 31B connected to the bottom-side oil chamber 18E of the opening-closing cylinder 18, and the tank line 29C connected to the tank 27. Therefore, when the pressure in the bottom-side oil chamber 18E of the opening-closing cylinder 18 rises to a pressure

(excess pressure) exceeding the relief pressure, the opening-closing cylinder relief valve 45 relieves the excess pressure to the tank 27. Consequently, the opening-closing cylinder 18 contracts by the amount the raising-lowering cylinder 12 extends, and the loosening of the raising-lowering rope 24 is removed. As a result, the spring member 36A of the loosening detection device 36 disengages from the detector 36B, causing the detector 36B to switch to the OFF state and the lowering stop valve 40 to switch to position (e). In this way, by removing the loosening of the raising-lowering rope 24, the weight of the clamshell bucket 10 holding earth and sand can be evenly distributed between the raising-lowering rope 24 and the opening-closing rope 25 (refer to FIG. 9). As a result, the clamshell bucket 10 can be stably lifted by the raising-lowering rope 24 and the opening-closing rope 25 without being lifted solely by the opening-closing rope 25. Additionally, the durability of the opening-closing rope 25 can be enhanced.

[0093] By distributing the weight of the clamshell bucket 10 between the raising-lowering rope 24 and the opening-closing rope 25 in this way, the force acting in the direction of contracting the opening-closing cylinder 18 decreases. As a result, when the pressure inside the bottom-side oil chamber 18E of the opening-closing cylinder 18 falls below the relief pressure of the opening-closing cylinder relief valve 45, the relief of excess pressure from the bottom-side oil chamber 18E to the tank line 29C is stopped. In this state, the operator continues to operate the raising-lowering operation device 32 toward the extension side and further extends the raising-lowering cylinder 12. As a result,

the raising-lowering rope 24 and the opening-closing rope 25 are pulled up toward the arm 7 side, and the clamshell bucket 10, while holding earth and sand, is lifted by the raising-lowering rope 24 and the opening-closing rope 25 and rises from the ground (refer to FIG. 10).

[0094] Here, when operating the raising-lowering operation device 32 toward the extension side to raise the clamshell bucket 10, the hydraulic fluid discharged from the hydraulic pump 26 and the hydraulic fluid discharged from the second hydraulic pump 46 merge by the confluence switching valve 47 and are supplied to the raising-lowering cylinder 12 (bottom-side oil chamber 12E). As a result, the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12 can be increased to extend the raising-lowering cylinder 12 quickly, increasing the raising speed of the clamshell bucket 10 and enhancing the efficiency of the excavation work.

[0095] On the other hand, when the clamshell bucket 10 lowers, friction occurs between the first raising-lowering sheave 14 and the second raising-lowering sheave 17 and the raising-lowering rope 24, as well as between the first opening-closing sheave 15 and the second opening-closing sheave 20 and the opening-closing rope 25. This may cause the speed (extension-contraction speed) of the raising-lowering cylinder 12 when contracting to become excessive compared to the lowering speed when the clamshell bucket 10 lowers by its own weight. In this case, the movement of the raising-lowering rope 24 and the opening-closing rope 25 cannot keep up with the extension-contraction speed of the raising-lowering cylinder 12, causing the raising-lowering rope

24 and the opening-closing rope 25 to become loosened, potentially coming into contact with surrounding structures and causing damage.

[0096] In contrast, when the raising-lowering operation device 32 is operated to the contraction side to lower the clamshell bucket 10, the confluence switching valve 47 switches to position (j), and hydraulic fluid discharged from the hydraulic pump 26 is supplied to the rod side oil chamber 12D of the raising-lowering cylinder 12, causing the clamshell bucket 10 to lower. In this way, during the lowering of the clamshell bucket 10, by supplying only the hydraulic fluid from the hydraulic pump 26 to the raising-lowering cylinder 12, it is possible to prevent an unnecessary increase in the flow rate of the hydraulic fluid.

[0097] As a result, excess hydraulic fluid is prevented from flowing into the rod side oil chamber 12D, and the speed at which the raising-lowering cylinder 12 contracts can correspond to the lowering speed of the clamshell bucket 10 under its own weight. This prevents the raising-lowering rope 24 and the opening-closing rope 25 from generating loosening and contacting surrounding structures, thereby extending the life of the raising-lowering rope 24 and the opening-closing rope 25. In addition, it is possible to prevent the fuel efficiency of the engine driving the hydraulic pump 26 and other components from deteriorating, and to prevent the temperature of the hydraulic fluid from rising excessively.

[0098] After raising the clamshell bucket 10 from the ground in this manner, for example, by rotating the upper swing body 3, the clamshell bucket 10 is moved above the load-carrying platform of a dump truck (not shown). Next, the operator turns OFF the operation

switch 50, and then operates the raising-lowering operation device 32 to the contraction side, lowering the clamshell bucket 10 towards the dump truck. The clamshell bucket 10 lowers as the first raising-lowering sheave 14 and the second raising-lowering sheave 17 approach each other, and the first opening-closing sheave 15 and the second opening-closing sheave 20 also approach each other due to the contraction operation of the raising-lowering cylinder 12.

[0099] Here, unlike the number of the first raising-lowering sheaves 14 and the second raising-lowering sheaves 17 exemplified in FIG. 4, in the actual machine of the deep foundation excavation machine 1, the raising-lowering rope 24 is wound around a plurality of first raising-lowering sheaves 14 and a plurality of second raising-lowering sheaves 17. Similarly, the opening-closing rope 25 is wound around a plurality of first opening-closing sheaves 15 and a plurality of second opening-closing sheaves 20. Therefore, since the lowering of the clamshell bucket 10 is performed quickly, if the raising-lowering operation device 32 is inadvertently operated too much to the contraction side, there is a risk that the clamshell bucket 10 collides with the dump truck.

[0100] In contrast, in this embodiment, by switching the operation switch 50 to OFF, the supply of electric power to the electromagnetic pilot portion 49A of the lowering pressure reducing valve 49 is stopped. Therefore, the pilot pressure flowing from the contraction side pressure reducing valve portion 32A of the raising-lowering operation device 32 through the pilot line 33A is supplied to the raising-lowering switching valve 30 via the lowering pressure reducing valve 49. As a result, the pilot

pressure supplied to the raising-lowering switching valve 30 is reduced by the lowering pressure reducing valve 49, allowing the lowering speed of the clamshell bucket 10 to be finely adjusted using the raising-lowering operation device 32. Consequently, it is possible to bring the clamshell bucket 10 closer to the dump truck at which the earth and sand should be unloaded without causing a collision, thereby enhancing the efficiency of the unloading operation.

[0101] In this way, after lowering the clamshell bucket 10 near the dump truck, the operator operates the opening-closing operation device 34 toward the contraction side. Thus, the pilot pressure from the contraction side pressure reducing valve portion 34A is supplied to the opening-closing switching valve 31 through the pilot line 35A, and the opening-closing switching valve 31 switches to position (c). As a result, the opening-closing cylinder 18 contracts, causing the second opening-closing sheave 20 to approach the first opening-closing sheave 15, and the opening-closing rope 25 is paid out. Consequently, the clamshell bucket 10 opens, and the excavated earth and sand are unloaded onto the dump truck's load-carrying platform.

[0102] Here, the opening-closing rope 25 is wound around the first opening-closing sheaves 15, the second opening-closing sheave 20, and a plurality of upper sheaves 10E and lower sheaves 10F installed on the clamshell bucket 10. Therefore, when the clamshell bucket 10 opens, friction occurs between the opening-closing rope 25 and the first opening-closing sheaves 15, the second opening-closing sheave 20, as well as the upper and lower sheaves 10E, 10F. As a result, if the contraction speed (extension-contraction speed)

of the opening-closing cylinder 18 becomes excessive compared to the speed at which the clamshell bucket 10 opens, the movement of the opening-closing rope 25 may not keep up with the extension-contraction speed of the opening-closing cylinder 18, resulting in loosening of the opening-closing rope 25 and coming into contact with surrounding structures, thereby causing damage.

[0103] In contrast, in this embodiment, a bucket opening pressure reducing valve 54 is provided in a pilot line 35A that connects the contraction side pressure reducing valve portion 34A of the opening-closing operation device 34 and the opening-closing switching valve 31. A set pressure (degree of pressure reduction) of the bucket opening pressure reducing valve 54 is adjusted so that, for example, the speed at which the opening-closing cylinder 18 contracts approaches the moving speed of the opening-closing rope 25 when the clamshell bucket 10 opens. This allows the speed at which the opening-closing cylinder 18 contracts to match the speed at which the clamshell bucket 10 opens. As a result, the opening-closing rope 25 is prevented from coming into contact with surrounding structures by preventing the loosening of the opening-closing rope 25, which extends the lifespan of the opening-closing rope 25.

[0104] In this manner, after the earth and sand are loaded onto the dump truck’s load-carrying platform, the earth and sand are leveled, for example, by collapsing the mound of earth and sand formed on the load-carrying platform while the clamshell bucket 10 is closed. First, when closing the opened clamshell bucket 10, the opening-closing operation device 34 is operated to the extension side. Thus, the pilot pressure from the extension side

pressure reducing valve portion 34B is supplied to the opening-closing switching valve 31 through the pilot line 35B without being reduced by the bucket opening pressure reducing valve 54. Consequently, the opening-closing switching valve 31 switches to position (d), and hydraulic fluid is supplied to the bottom-side oil chamber 18E of the opening-closing cylinder 18, allowing the opening-closing cylinder 18 to extend quickly and rapidly close the clamshell bucket 10.

[0105] Next, when raising-lowering the closed clamshell bucket 10 to collapse the mound of earth and sand, the operations to extend and contract the raising-lowering operation device 32 are repeated. When lowering the clamshell bucket 10 to collapse the mound of earth and sand, it is necessary to carefully lower the clamshell bucket 10 to avoid contact with the load-carrying platform. For this reason, the operator turns the operation switch 50 OFF, stopping the supply of electric power to the electromagnetic pilot portion 48A of the raising pressure reducing valve 48 and to the electromagnetic pilot portion 49A of the lowering pressure reducing valve 49. In this state, by operating the raising-lowering operation device 32 toward the contraction side, the pilot pressure from the contraction side pressure reducing valve portion 32A is supplied to the raising-lowering switching valve 30 in a pressure-reduced state by the lowering pressure reducing valve 49. This allows the raising-lowering cylinder 12 to be slowly contracted, reducing the lowering speed of the clamshell bucket 10, enabling the collapse of the mound of earth and sand.

[0106] On the other hand, when raising the clamshell bucket 10 after collapsing the mound of earth and sand, the operator turns

the operation switch 50 ON, supplying electric power to the electromagnetic pilot portion 48A of the raising pressure reducing valve 48 and the electromagnetic pilot portion 49A of the lowering pressure reducing valve 49. In this state, by operating the raising-lowering operation device 32 toward the extension side, the pilot pressure from the extension side pressure reducing valve portion 32B bypasses the raising pressure reducing valve 48 and is supplied to the raising-lowering switching valve 30, which quickly switches to position (b). Additionally, by switching the confluence switching valve 47 to position (k) through the pilot pressure from the extension side pressure reducing valve portion 32B, the hydraulic fluid discharged from the hydraulic pump 26 and the hydraulic fluid discharged from the second hydraulic pump 46 merge and are supplied to the bottom-side oil chamber 12E of the raising-lowering cylinder 12. As a result, the speed at which the clamshell bucket 10 rises can be increased.

[0107] In this way, the operator can finely adjust the raising-lowering speed of the clamshell bucket 10 by operating the operation switch 50, which is provided inside the cab 4, to turn it ON/OFF. Thus, it is possible to continuously perform the operation of carefully lowering the clamshell bucket 10 to avoid contact with the load-carrying platform while collapsing the mound of earth and sand, and the operation of rapidly raising the clamshell bucket 10 from the mound of earth and sand. As a result, the task of leveling the earth and sand loaded onto the dump truck's load-carrying platform can be performed rapidly, enhancing the efficiency of the excavation work.

[0108] After loading earth and sand onto the dump truck's

load-carrying platform and leveling the mound of earth and sand, for example, the upper swing body 3 is rotated to move the clamshell bucket 10 above the vertical shaft, and the aforementioned operations are repeated, allowing the excavation work on the vertical shaft to continue.

[0109] Thus, the deep foundation excavation machine 1 according to the embodiment consists of a self-propelled vehicle body and a work device 5 attached to the vehicle body. The work device 5 comprises an arm 7 rotatably attached to the vehicle body, a clamshell bucket 10 raisably and lowerably attached to the arm for excavating vertical shafts, and a bucket raising-lowering and opening-closing device 11 attached to the arm for raising-lowering and opening-closing the clamshell bucket. The bucket raising-lowering and opening-closing device 11 includes a raising-lowering cylinder 12 mounted on the arm 7, a first raising-lowering sheave 14 and a first opening-closing sheave 15 mounted on one end of the raising-lowering cylinder 12 and moving in the extension-contraction direction of the raising-lowering cylinder 12, a second raising-lowering sheave 17 attached at a distance from the first raising-lowering sheave 14 on the arm 7, a second opening-closing sheave 20 attached at a distance from the first opening-closing sheave 15 on the arm 7, an opening-closing cylinder 18 that moves the second opening-closing sheave 20 close to and apart from the first opening-closing sheave 15 to open and close the clamshell bucket 10, a raising-lowering rope 24 with one end attached to the arm 7 and the other end attached to the clamshell bucket 10, and its intermediate portion wound around the first raising-lowering sheave 14 and the second

raising-lowering sheave 17, and an opening-closing rope 25 with one end attached to the arm 7 and the other end attached to the clamshell bucket 10, and its intermediate portion wound around the first opening-closing sheave 15 and the second opening-closing sheave 20. The stroke length of the opening-closing cylinder 18 is set to a value equal to or greater than a sum obtained by adding a stroke length corresponding to the opening-closing range of the clamshell bucket 10 and a stroke length corresponding to the amount of loosening of the opening-closing rope 25 that occurs after the clamshell bucket 10 lands and until the raising-lowering cylinder 12 stops. Additionally, the deep foundation excavation machine 1 according to the embodiment includes at least one of an opening-closing cylinder relief valve 45 that relieves excessive pressure in the opening-closing cylinder 18 when the weight of the clamshell bucket 10 acts on the opening-closing rope 25, a raising-lowering flow rate adjustment device (second hydraulic pump 46 and confluence switching valve 47) that varies the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12 when the clamshell bucket 10 is lowered, and a raising-lowering speed adjustment device (raising pressure reducing valve 48 and lowering pressure reducing valve 49) that adjusts the raising-lowering speed of the clamshell bucket 10 when the clamshell bucket 10 is raised and lowered.

[0110] According to the configuration including the opening-closing cylinder relief valve 45, when the clamshell bucket 10 lands, by providing appropriate loosening to the raising-lowering rope 24 and the opening-closing rope 25, the clamshell bucket 10 is allowed to dig into the ground, enabling

the scooping of a large amount of sand and earth. When the clamshell bucket 10 scoops the earth and sand, and the clamshell bucket 10 is raised by the raising-lowering cylinder 12, until the loosening of the raising-lowering rope 24 is removed, the weight of the clamshell bucket 10 acts only on the opening-closing rope 25, and excess pressure is generated within the opening-closing cylinder 18. By relieving this excess pressure with the opening-closing cylinder relief valve 45, the opening-closing cylinder 18 can be extended and contracted according to the stroke of the raising-lowering cylinder 12. Additionally, by the extension-contraction operation of the opening-closing cylinder 18, both removing the loosening of the raising-lowering rope 24 and opening and closing the clamshell bucket 10 can be performed.

[0111] Therefore, without installing a dedicated device such as a loosening removal cylinder to remove the loosening of the opening-closing rope, it is possible to use the opening-closing cylinder 18 to remove the loosening of the opening-closing rope 25. As a result, the cumbersome work of removing the loosening of the opening-closing rope 25 using a dedicated device such as a loosening removal cylinder is unnecessary, thus enhancing the efficiency of the excavation work. Moreover, the work of removing the loosening of the opening-closing rope 25 and the work of closing the clamshell bucket 10 to scoop the earth and sand can be continuously performed by the extension operation of the opening-closing cylinder 18. As a result, for example, compared to using a dedicated device such as a loosening removal cylinder, it is possible to eliminate the time lag between the removal of the loosening of the opening-closing rope 25 and the beginning

of closing the clamshell bucket 10, thereby improving the efficiency of excavation work. Furthermore, since the opening-closing rope 25 is looped a plurality of times around the second opening-closing sheave 20, it is possible to quickly remove the loosening of the opening-closing rope 25, compared to using a dedicated device such as a loosening removal cylinder. In addition, by eliminating the need for a dedicated device such as a loosening removal cylinder, it is possible to reduce the number of components, decrease the weight of the bucket raising-lowering and opening-closing device 11, and contribute to cost reduction.

[0112] Further, according to the configuration including the raising-lowering flow rate adjustment device (second hydraulic pump 46 and confluence switching valve 47), for example, when the clamshell bucket 10 is raised, the hydraulic fluid discharged from the hydraulic pump 26 and the hydraulic fluid discharged from the second hydraulic pump 46 merge and are supplied to the raising-lowering cylinder 12 by the confluence switching valve 47. As a result, it is possible to increase the speed at which the clamshell bucket 10 rises, thus improving the efficiency of excavation work. On the other hand, when the clamshell bucket 10 is lowered, only the hydraulic fluid from the hydraulic pump 26 is supplied to the raising-lowering cylinder 12, which can suppress an unnecessary increase in the flow rate of the hydraulic fluid. This makes it possible to avoid a problem where, for example, during the lowering of the clamshell bucket 10, the raising-lowering speed of the raising-lowering cylinder 12 becomes excessive, causing the raising-lowering rope 24 wound around both the second raising-lowering sheave 17 and the first raising-lowering sheave

14 to become loosened due to an inability to follow the movement of the first raising-lowering sheave 14. As a result, it is possible to prevent the raising-lowering rope 24 from becoming loosened and from coming into contact with surrounding structures during the lowering of the clamshell bucket 10, thus enhancing the efficiency of excavation work. Furthermore, it is possible to prevent the deterioration of fuel efficiency of the engine driving the hydraulic pump 26 and other components, as well as prevent the hydraulic fluid temperature from rising unnecessarily.

[0113] Moreover, according to the configuration including the raising-lowering speed adjustment device (the raising pressure reducing valve 48 and the lowering pressure reducing valve 49), the flow rate of pilot pressure supplied from the raising-lowering operation device 32 to the raising-lowering switching valve 30 that controls the extension-contraction operation of the raising-lowering cylinder 12 can be varied by the raising pressure reducing valve 48 and the lowering pressure reducing valve 49, allowing the adjustment of the raising-lowering speed of the clamshell bucket 10. This allows for the precise adjustment of the lowering speed of the clamshell bucket 10 by the raising-lowering operation device 32, as the pilot pressure supplied to the raising-lowering switching valve 30 is reduced by the lowering pressure reducing valve 49. As a result, it is possible to approach a dump truck where the earth and sand are to be discharged without colliding the clamshell bucket 10, thereby enhancing the efficiency of the unloading operation.

[0114] In this embodiment, the deep foundation excavation machine 1 includes the bucket flow rate adjustment device (the bucket

opening pressure reducing valve 54) that adjusts the flow rate of hydraulic fluid supplied to the opening-closing cylinder 18 when opening the clamshell bucket 10. According to this configuration, for example, the flow rate of pilot pressure supplied to the opening-closing switching valve 31, which controls the extension-contraction operation of the opening-closing cylinder 18, is reduced by the bucket opening pressure reducing valve 54, and it is possible to decrease the speed at which the clamshell bucket 10 opens. As a result, it is possible to prevent the opening-closing rope 25 from becoming loosened and from coming into contact with surrounding structures, thereby extending the lifespan of the opening-closing rope 25.

[0115] In this embodiment, the raising-lowering flow rate adjustment device increases the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12 when raising the clamshell bucket 10, compared to the flow rate supplied when lowering the clamshell bucket 10. According to this configuration, when lowering the clamshell bucket 10, it is possible to prevent the extension-contraction speed of the raising-lowering cylinder 12 from becoming excessive and causing loosening of the raising-lowering rope 24. When raising the clamshell bucket 10, by increasing the extension-contraction speed of the raising-lowering cylinder 12, the raising speed of the clamshell bucket 10 can be enhanced, thereby improving the efficiency of excavation work.

[0116] In this embodiment, the raising-lowering speed adjustment device includes the operation switch 50 operated by an operator to switch the raising-lowering speed of the clamshell bucket 10.

According to this configuration, for example, after excavating earth and sand with the clamshell bucket 10, by setting the raising-lowering speed (raising speed) of the clamshell bucket 10 to a high level with the operation switch 50, the clamshell bucket 10 can be quickly raised above the load-carrying platform of a dump truck. On the other hand, for example, when loading earth and sand held by the clamshell bucket 10 onto a dump truck, by setting the raising-lowering speed (lowering speed) of the clamshell bucket 10 lower with the operation switch 50, the clamshell bucket 10 can be carefully lowered close to the load-carrying platform without contacting the dump truck. In this way, by the operator operating the operation switch 50 to appropriately switch the raising-lowering speed of the clamshell bucket 10 according to the excavation work conditions, the efficiency of the excavation work can be enhanced.

[0117] The embodiment exemplifies a case where a hydraulic circuit for driving components such as the raising-lowering cylinder 12 and the opening-closing cylinder 18 that constitute the bucket raising-lowering and opening-closing device 11 is equipped with an opening-closing cylinder relief valve 45, a raising-lowering flow rate adjustment device (the second hydraulic pump 46 and the confluence switching valve 47), and a raising-lowering speed adjustment device (the raising pressure reducing valve 48 and lowering pressure reducing valve 49). However, the present invention is not limited to this, and it is also possible to install at least one of the opening-closing cylinder relief valve 45, the raising-lowering flow rate adjustment device, and the raising-lowering speed adjustment device.

[0118] Moreover, in this embodiment, a second hydraulic pump 46 and a confluence switching valve 47 are used as a raising-lowering flow rate adjustment device that varies the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12. It exemplifies a case where, during the lowering of the clamshell bucket 10, the hydraulic fluid discharged from the hydraulic pump 26 is supplied to the raising-lowering cylinder 12, and during the raising of the clamshell bucket 10, the hydraulic fluid discharged from the second hydraulic pump 46 is merged with the hydraulic fluid discharged from the hydraulic pump 26 and is supplied to the raising-lowering cylinder 12. However, the present invention is not limited to this, and it is also possible to vary the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12 during both the lowering and raising of the clamshell bucket 10 by changing the engine speed to vary the discharge amount of the hydraulic pump.

[0119] Furthermore, in this embodiment, the raising pressure reducing valve 48 and lowering pressure reducing valve 49 are used as raising-lowering speed adjustment devices for adjusting the raising-lowering speed when raising and lowering the clamshell bucket 10. It exemplifies a case where the raising pressure reducing valve 48 and the lowering pressure reducing valve 49 enable the adjustment of the flow rate of pilot pressure supplied to the raising-lowering switching valve 30, thereby adjusting the raising-lowering speed of the clamshell bucket 10. However, the present invention is not limited to this, and it is also possible to vary the flow rate of hydraulic fluid supplied to the raising-lowering cylinder 12 and adjust the raising-lowering

speed of the clamshell bucket 10 by changing the engine speed to vary the discharge amount of the hydraulic pump.

[0120] Additionally, in this embodiment, when the raising-lowering cylinder 12 is contracted, the clamshell bucket 10 lowers, and when it is extended, the clamshell bucket 10 raises. However, the present invention is not limited to this, and it could also be configured such that when the raising-lowering cylinder 12 is contracted, the clamshell bucket 10 raises, and when it is extended, the clamshell bucket 10 lowers. Similarly, the extension-contraction operation of the opening-closing cylinder 18 and the opening-closing operation of the clamshell bucket 10 could be reversed.

[0121] Furthermore, in this embodiment, a case is exemplified where the arm 7 is formed as an elongated square tube, with the bucket raising-lowering and opening-closing device 11 mounted on its outer periphery. However, the present invention is not limited to this, and it could also be configured, for example, by forming the arm 7 as an elongated square tube and installing the bucket raising-lowering and opening-closing device 11 inside it.

DESCRIPTION OF REFERENCE NUMERALS

[0122] 1: Deep foundation excavation machine

2: Lower travel body (vehicle body)

3: Upper swing body (vehicle body)

5: Work device

7: Arm

10: Clamshell bucket

11: Bucket raising-lowering and opening-closing device

12: Raising-lowering cylinder

14: First raising-lowering sheave

15: First opening-closing sheave

17: Second raising-lowering sheave

18: Opening-closing cylinder

20: Second opening-closing sheave

24: Raising-lowering rope

25: Opening-closing rope

45: Opening-closing cylinder relief valve

46: Second hydraulic pump (flow rate adjustment device for raising-lowering)

47: Confluence switching valve (raising-lowering flow rate adjustment device)

48: Raising pressure reducing valve (raising-lowering speed adjustment device)

49: Lowering pressure reducing valve (raising-lowering speed adjustment device)

50: Operation switch

54: Bucket opening pressure reducing valve (bucket flow rate adjustment device)

CLAIMS

Claim 1. A deep foundation excavation machine comprising

a self-propelled vehicle body and a work device attached to the vehicle body, wherein

the work device includes an arm rotatably attached to the vehicle body, a clamshell bucket raisably and lowerably attached to the arm for excavating a vertical shaft, and a bucket raising-lowering and opening-closing device attached to the arm for raising, lowering, opening, and closing the clamshell bucket,

the bucket raising-lowering and opening-closing device includes:

a raising-lowering cylinder attached to the arm;

a first raising-lowering sheave and a first opening-closing sheave attached to one end side of the raising-lowering cylinder and movable in an extension-contraction direction of the raising-lowering cylinder;

a second raising-lowering sheave attached to the arm at a distance from the first raising-lowering sheave;

a second opening-closing sheave attached to the arm at a distance from the first opening-closing sheave;

an opening-closing cylinder that opens and closes the clamshell bucket by moving the second opening-closing sheave toward and away from the first opening-closing sheave;

a raising-lowering rope having one end attached to the arm and another end attached to the clamshell bucket, with an intermediate portion wound around the first and the second raising-lowering sheaves; and

an opening-closing rope having one end attached to the arm and another end attached to the clamshell bucket, with an intermediate portion wound around the first and the second opening-closing sheaves,

a stroke length of the opening-closing cylinder is set to a value equal to or greater than a sum of a stroke length corresponding to an opening-closing range of the clamshell bucket and a stroke length corresponding to a loosening amount of the opening-closing rope that occurs between when the clamshell bucket lands and when the raising-lowering cylinder stops, and

the deep foundation excavation machine further comprises at least one of:

an opening-closing cylinder relief valve that relieves excessive pressure in the opening-closing cylinder when a weight of the clamshell bucket acts on the opening-closing rope;

a raising-lowering flow rate adjustment device capable of varying a flow rate of hydraulic fluid supplied to the raising-lowering cylinder at a time of raising the clamshell bucket and a flow rate of hydraulic fluid supplied to the raising-lowering cylinder at a time of lowering the clamshell bucket; and

a raising-lowering speed adjustment device that adjusts a raising-lowering speed of the clamshell bucket at the time of raising and at the time lowering the clamshell bucket.

Claim 2. The deep foundation excavation machine according to claim 1, wherein

the deep foundation excavation machine further comprises a bucket flow rate adjustment device that adjusts a flow rate of

hydraulic fluid supplied to the opening-closing cylinder at a time of opening the clamshell bucket.

Claim 3. The deep foundation excavation machine according to claim 1, wherein

the raising-lowering flow rate adjustment device increases the flow rate of the hydraulic fluid supplied to the raising-lowering cylinder at the time of raising the clamshell bucket to be more than the flow rate of the hydraulic fluid supplied to the raising-lowering cylinder at the time of lowering the clamshell bucket.

Claim 4. The deep foundation excavation machine according to claim 1, wherein

the raising-lowering speed adjustment device includes an operation switch operated by an operator to change the raising-lowering speed of the clamshell bucket.