

A Method for Relay Pump Installation and Slurry Discharge During Shield Tunneling

Technical Field

The present invention relates to the field of shield tunnel engineering, and in particular to a method for relay pump installation and slurry discharge during shield tunneling.

Background Art

In the construction process of a slurry shield, a slurry chamber is formed between the cutterhead and the bulkhead of the shield machine. High-quality slurry is fed into the slurry chamber by a ground-based slurry feed pump; on the excavation face, pressurization of the slurry forms an impermeable or minimally permeable mud film, and the slurry pressure in the slurry chamber balances the earth pressure and water pressure at the excavation face through the mud film. During shield machine tunneling, the excavated muck cut by the cutterhead is mixed with the slurry in the slurry chamber through cutterhead agitation; the mixed slurry is then pumped and transported to the surface backend slurry treatment station via a slurry discharge pump, where it undergoes screening treatment, and after adjustment in an adjustment tank, is recycled for reuse, thereby achieving the removal of excavated muck from the shield tunneling operation.

The slurry shield system relies on continuous circulation by slurry feed pumps and slurry discharge pumps; however, for long-distance tunnels, owing to the limitations imposed by the pump head, slurry specific gravity, transport distance, elevation difference, and other factors on pump performance, a single slurry feed pump and a single slurry discharge pump are far from sufficient to meet the construction requirements of the entire tunnel. Therefore, after the shield machine tunneling has advanced a certain distance, relay pumps need to be added to ensure the normal operation of the entire slurry circulation system.

In existing slurry shield construction, the conventional method for adding relay pumps is as follows: after the slurry circulation load reaches its limit, the shield machine is shut down, the existing slurry pipes are removed, and the relay pump is then installed. However, the existing construction method requires stopping shield tunneling operations, disconnecting the slurry pipeline, and then connecting the relay pump; this method necessitates a prolonged shutdown of shield construction, which severely impacts and constrains the tunneling progress of the

shield machine.

Summary of the Invention

The present invention provides a method for relay pump installation and slurry discharge during shield tunneling, which solves the problem of low construction efficiency of shield machines in the prior art.

To achieve the above objective, the present invention adopts the following technical solution:

The present invention provides a method for relay pump installation and slurry discharge during shield tunneling, the method comprising:

based on the pre-determined relay pump installation position, a branch slurry pipe is used at the relay pump installation position during construction of the slurry pipeline system; the branch slurry pipe comprises a main slurry pipe, wherein the middle of the main slurry pipe is provided with a main control switch, and a first branch pipe and a second branch pipe communicatively disposed on the main slurry pipe, the first branch pipe and the second branch pipe being oppositely arranged on both sides of the main control switch, with the openings of the first branch pipe and the second branch pipe both sealed by blind plates;

after the shield pipe replacement zone reaches the relay pump installation position, the first switch and the second switch are used to replace the blind plates at the openings of the first branch pipe and the second branch pipe, respectively; the first branch pipe is connected to the slurry inlet of the relay pump to be installed via the first connecting pipe, and the second branch pipe is connected to the slurry outlet of the relay pump via the second connecting pipe; the first switch is used to control the communication between the first branch pipe and the first connecting pipe, and the second switch is used to control the communication between the second branch pipe and the second connecting pipe;

a pressure gauge for monitoring slurry pressure is provided at the inlet of the relay pump, a torque meter for monitoring the impeller rotation torque within the relay pump is provided at the motor shaft of the relay pump, and an accelerometer for monitoring the vibration intensity during operation of the relay pump is provided on the pump body of the relay pump;

based on the monitored slurry pressure, the impeller rotation torque, and the vibration

intensity, determining whether the relay pump has malfunctioned;

upon determining that the relay pump has malfunctioned, opening the main control switch, closing the first switch and/or the second switch, and switching to the main slurry pipe for slurry discharge operations.

In one possible implementation, when the first connecting pipe comprises a first bent section and a first straight section, the step of connecting the first branch pipe to the slurry inlet of the relay pump to be installed via the first connecting pipe specifically comprises:

disposing the relay pump below the branch slurry pipe, disposing the slurry outlet at the top of the relay pump, and disposing the slurry inlet on the side wall of the relay pump;

connecting one end of the first bent section to the first branch pipe, communicating the other end of the first bent section with one end of the first straight section, communicating the other end of the first straight section with the slurry inlet, and setting the angle between the first straight section and the horizontal plane to -15° to -20° .

In one possible implementation, when the second connecting pipe comprises a second bent section and a second straight section, the step of connecting the second branch pipe to the slurry outlet of the relay pump via the second connecting pipe specifically comprises:

communicating one end of the second bent section with the slurry outlet, communicating the other end of the second bent section with one end of the second straight section, connecting one end of the second straight section to the second branch pipe, and setting the angle between the second straight section and the horizontal plane to 30° to 40° .

In one possible implementation, the first bent section and the first straight section are connected via a flexible pipe, and the second bent section and the second straight section are connected via a flexible pipe.

In one possible implementation, the step of determining whether the relay pump has malfunctioned based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity specifically comprises:

determining whether the relay pump has experienced a blockage fault based on the relationship between the monitored slurry pressure and a preset pressure value, and the relationship between the monitored impeller rotation torque and a preset torque value;

determining whether the relay pump has experienced a fault of stones being mixed into the pump body or stones being jammed in the impeller based on the relationship between the monitored vibration intensity and a preset vibration value.

In one possible implementation, while determining whether the relay pump has malfunctioned based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity, the method further comprises:

taking a first preset percentage of the preset pressure value, the preset torque value, and the preset vibration value as the warning threshold values for the slurry pressure, the impeller rotation torque, and the vibration intensity, respectively;

upon the monitored slurry pressure, the impeller rotation torque, and the vibration intensity each reaching the respective warning threshold values, triggering the corresponding warning function.

In one possible implementation, while determining whether the relay pump has malfunctioned based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity, the method further comprises:

taking a second preset percentage of the preset pressure value, the preset torque value, and the preset vibration value as the alarm values for the slurry pressure, the impeller rotation torque, and the vibration intensity, respectively, wherein the second preset percentage is greater than the first preset percentage;

upon the monitored slurry pressure, the impeller rotation torque, and the vibration intensity each reaching the respective alarm values, triggering the corresponding emergency alarm function.

In one possible implementation, after determining that the relay pump has malfunctioned, the method further comprises:

activating a high pressure flushing device to inject high pressure water toward the first connecting pipe, the second connecting pipe, and the pump body inlet and pump body bottom of the relay pump, so as to flush the slurry inside the first connecting pipe and the second connecting pipe, as well as the slurry at the relay pump impeller, inlet channel, and pump body bottom.

In one possible implementation, before the shield pipe replacement zone reaches the relay pump installation position, the method further comprises:

performing advance casting of the tunnel internal structural lining, filling and compacting the box culverts, and constructing an installation base at the relay pump installation position; the installation base is used to secure the relay pump.

In one possible implementation, before incorporating the relay pump into the slurry pipeline system, the method further comprises:

commissioning the relay pump to ensure normal operation of the relay pump.

In actual application, the method for relay pump installation and slurry discharge during shield tunneling provided by the embodiments of the present invention requires no stoppage of shield tunneling operations: after the shield pipe replacement zone reaches the relay pump installation position, the cover plate at the opening of the first branch pipe is replaced via the first switch, and the cover plate at the opening of the second branch pipe is replaced via the second switch; subsequently, the first branch pipe is connected to the slurry inlet of the relay pump via the first connecting pipe, and the second branch pipe is connected to the slurry outlet of the relay pump via the second connecting pipe; opening the first switch enables communication between the first branch pipe and the slurry inlet, opening the second switch enables communication between the second branch pipe and the slurry outlet, and simultaneously closing the main control switch incorporates the added relay pump into the slurry pipeline system, thereby achieving relay pump installation during ongoing shield machine tunneling operations, saving construction time and improving construction efficiency.

After the relay pump is incorporated into the slurry pipeline system, a pressure gauge is provided at the inlet of the relay pump to monitor the incoming slurry pressure in real time; a torque meter is provided at the motor shaft of the relay pump to monitor the impeller rotation torque within the relay pump; an accelerometer is provided on the pump body of the relay pump to monitor the vibration intensity during relay pump operation; whether the relay pump has malfunctioned is determined based on the real-time monitored slurry pressure, impeller rotation torque, and vibration intensity against the corresponding preset threshold values; upon detecting a relay pump malfunction, the main control switch is opened and the first

switch and/or the second switch is simultaneously closed, switching to the main slurry pipe for slurry dispatch operations; after the relay pump maintenance is completed, operations are switched back to the relay pump branch for slurry discharge; throughout the entire process, the shield machine does not stop, ensuring the construction efficiency of the shield machine.

Brief Description of the Drawings

FIG. 1 is a step flow chart of a method for relay pump installation and slurry discharge during shield tunneling provided by the embodiments of the present invention;

FIG. 2 is a structural schematic diagram of a branch slurry pipe in the method for relay pump installation and slurry discharge during shield tunneling provided by the embodiments of the present invention;

FIG. 3 is a structural schematic diagram of the relay pump being added to the slurry pipeline system in the method for relay pump installation and slurry discharge during shield tunneling provided by the embodiments of the present invention.

Reference Signs and Descriptions:

1, branch slurry pipe; 11, main slurry pipe; 12, main control switch; 13, first branch pipe; 14, second branch pipe; 15, blind plate; 2, relay pump; 21, first switch; 22, second switch; 23, first bent section; 24, first straight section; 25, second bent section; 26, second straight section; 27, flexible pipe; 28, installation base.

Detailed Description of Embodiments

The technical solutions in the embodiments of the present invention will be described clearly and completely with reference to the accompanying drawings in the embodiments of the present invention; obviously, the described embodiments are merely some embodiments of the present invention, not all embodiments. Based on the embodiments of the present invention, all other embodiments obtained by persons of ordinary skill in the art without creative effort fall within the scope of protection of the present invention.

Hereinafter, the terms “first” and “second” are used for descriptive purposes only and shall not be construed as indicating or implying relative importance or implicitly specifying the number of the indicated technical features. Thus, a feature qualified with “first” or “second” may explicitly or implicitly include one or more of such features. In the description of the embodiments of the present disclosure, unless otherwise stated, the meaning of “plurality” is two or more. Furthermore, the use of “based on” or “according to” implies openness and inclusiveness, as a process, step, calculation, or other action “based on” or “according to” one or more of the stated conditions or values may in practice be based on additional conditions or values beyond those stated.

In order to solve the problem in the prior art that shield tunneling operations need to be stopped when installing a relay pump, the embodiments of the present invention provide a method for relay pump installation and slurry discharge during shield tunneling.

As shown in Figs. 1 to 3, a relay pump 2 slurry discharge method without stopping the shield machine comprises:

Step 101: Based on the pre-determined installation position of relay pump 2, a branch slurry pipe is used at the installation position of relay pump 2 during construction of the slurry pipeline system.

The slurry pipeline system comprises a slurry feed pipe and a slurry discharge pipe connected to the shield machine, wherein the slurry feed pipe is provided with a slurry feed pump and the slurry discharge pipe is provided with a slurry discharge pump. For longer tunnels, owing to the limitations of slurry pump performance in terms of pump head, flow rate, and other parameters, a single slurry feed pump and a single slurry discharge pump are far from sufficient to meet the construction requirements of the entire tunnel; this necessitates the addition of relay pump 2 stations in the middle of the tunnel after the shield tunneling has advanced a certain distance, so as to ensure the normal operation of the entire slurry circulation system.

Relay pump 2 mainly consists of a slurry pump and its matching drive control system. As a part of the slurry circulation system, relay pump 2 is operated remotely by the chief operator

in the shield main control room; through the relay coordination of several pumps within the performance range of each pump, the flow rate and pressure of the pumped slurry are ensured.

As shown in FIG. 2, the branch slurry pipe 1 comprises a main slurry pipe 11, wherein the middle of the main slurry pipe 11 is provided with a main control switch 12, as well as a first branch pipe 13 and a second branch pipe 14 communicatively disposed on the main slurry pipe 11; the first branch pipe 13 and the second branch pipe 14 are oppositely arranged on both sides of the main control switch 12, and the openings of the first branch pipe 13 and the second branch pipe 14 are both sealed by blind plates 15.

The main slurry pipe 11 is formed by splicing two slurry pipes with Y-shaped branches, and the splice joint of the two slurry pipes is connected via the main control switch 12.

Step 102: After the shield pipe replacement zone reaches the installation position of relay pump 2, as shown in FIG. 3, the first switch 21 and the second switch 22 are used to replace the blind plates 15 at the openings of the first branch pipe 13 and the second branch pipe 14, respectively; the first branch pipe 13 is connected to the slurry inlet of the relay pump 2 to be installed via the first connecting pipe, the second branch pipe 14 is connected to the slurry outlet of relay pump 2 via the second connecting pipe, and relay pump 2 is incorporated into the slurry pipeline system.

The first switch 21 is used to control the communication between the first branch pipe 13 and the first connecting pipe, and the second switch 22 is used to control the communication between the second branch pipe 14 and the second connecting pipe.

Incorporating relay pump 2 into the slurry pipeline system specifically requires opening the first switch 21 and the second switch 22 while simultaneously closing the main control switch 12.

Before the shield pipe replacement zone reaches the installation position of relay pump 2, the openings of the first branch pipe 13 and the second branch pipe 14 are both sealed by blind plates 15 to prevent slurry from leaking from the openings of the first branch pipe 13 and the second branch pipe 14.

Specifically, the angles between the first branch pipe 13 and the second branch pipe 14 and the main slurry pipe 11 are both 25° to 35° .

The lengths of the first branch pipe 13 and the second branch pipe 14 are both 70 to 90 cm.

In this embodiment, the angles between the first branch pipe 13 and the second branch pipe 14 and the main slurry pipe 11 are both 30° , and the lengths of the first branch pipe 13 and the second branch pipe 14 are both 80 cm.

Specifically, the main control switch 12, the first switch 21, and the second switch 22 are all gate valves.

To facilitate the connection between pipes, the gate valves of the first switch and the second switch are also provided with slurry pipelines of approximately 50 cm in length on the exterior.

During the installation of the gate valves, attention should also be paid to the flow interception direction of the gate valves, to prevent subsequent steps from being unable to proceed due to gate valve leakage after the pipeline installation is completed.

Step 103: A pressure gauge for monitoring slurry pressure is provided at the inlet of relay pump 2; a torque meter for monitoring the impeller rotation torque within relay pump 2 is provided at the motor shaft of relay pump 2; and an accelerometer for monitoring the vibration intensity during operation of relay pump 2 is provided on the pump body of relay pump 2.

The pressure gauge, torque meter, and accelerometer are all sensors that automatically collect data 24 hours a day with real-time upload for monitoring.

Step 104: Based on the monitored slurry pressure, impeller rotation torque, and vibration intensity, determine whether relay pump 2 has malfunctioned.

Specifically, whether relay pump 2 has malfunctioned can be determined by comparing the collected values of slurry pressure, impeller rotation torque, and vibration intensity against the corresponding threshold values for the project.

For example, when the collected vibration intensity value exceeds the preset threshold value corresponding to the vibration intensity, relay pump 2 is considered to have malfunctioned.

Step 105: After determining that relay pump 2 has malfunctioned, open the main control switch 12, close the first switch 21 and/or the second switch 22, and switch to the main slurry pipe 11 for slurry discharge operations.

Specifically, after the installation of relay pump 2, slurry transport within that section is normally achieved through relay pump 2; however, when relay pump 2 malfunctions, slurry transport can be temporarily switched to the main slurry pipe, ensuring that relay pump 2 can be maintained while the shield machine continues operating without stopping.

Further, as shown in FIG. 3, when the first connecting pipe comprises a first bent section 23 and a first straight section 24, the step of connecting the first branch pipe 13 to the slurry inlet of the relay pump 2 to be installed via the first connecting pipe specifically comprises:

- disposing relay pump 2 below the branch slurry pipe 1, disposing the slurry outlet at the top of relay pump 2, and disposing the slurry inlet on the side wall of relay pump 2;

- connecting one end of the first bent section 23 to the first branch pipe 13, communicating the other end of the first bent section 23 with one end of the first straight section 24, communicating the other end of the first straight section 24 with the slurry inlet, and setting the angle between the first straight section 24 and the horizontal plane to -15° to -20° .

Further, when the second connecting pipe comprises a second bent section 25 and a second straight section 26, the step of connecting the second branch pipe 14 to the slurry outlet of relay pump 2 via the second connecting pipe specifically comprises:

- communicating one end of the second bent section 25 with the slurry outlet,

communicating the other end of the second bent section 25 with one end of the second straight section 26, connecting one end of the second straight section 26 to the second branch pipe 14, and setting the angle between the second straight section 26 and the horizontal plane to 30° to 40°.

Further, in order to improve the alignment precision between the first bent section 23 and the first straight section 24, and between the second bent section 25 and the second straight section 26, and to reduce the difficulty of connection, the first bent section 23 and the first straight section 24 are connected via a flexible pipe 27, and the second bent section 25 and the second straight section 26 are also connected via a flexible pipe 27.

The flexible pipe 27 may be a rubber connecting pipe.

To facilitate user observation of the slurry flow condition, observation windows may be provided on the first connecting pipe and the second connecting pipe, or the flexible pipe 27 may be made of a semi-transparent material.

Further, determining whether relay pump 2 has malfunctioned based on the monitored slurry pressure, impeller rotation torque, and vibration intensity specifically comprises:

Determining whether relay pump 2 has experienced a blockage fault based on the comparison of the monitored slurry pressure against the preset pressure threshold value, and the comparison of the monitored impeller rotation torque against the preset torque threshold value.

Specifically, when the monitored slurry pressure exceeds the preset pressure threshold value while the monitored impeller rotation torque also exceeds the preset torque threshold value, relay pump 2 is considered to have experienced a blockage fault.

Determining whether relay pump 2 has experienced a fault caused by stones entering the pump body or becoming lodged in the impeller, based on the comparison of the monitored vibration intensity against the preset vibration threshold value.

Specifically, when the monitored vibration intensity exceeds the preset vibration threshold

value, relay pump 2 is considered to have experienced a fault caused by stones entering the pump body or becoming lodged in the impeller.

The magnitudes of the preset pressure threshold value, preset torque threshold value, and preset vibration threshold value are determined based on long-term construction experience.

Further, while determining whether relay pump 2 has malfunctioned based on the monitored slurry pressure, impeller rotation torque, and vibration intensity, the method further comprises:

Taking a first preset percentage of the preset pressure threshold value, preset torque threshold value, and preset vibration threshold value as the respective warning threshold values for slurry pressure, impeller rotation torque, and vibration intensity.

Specifically, the first preset percentage may be 70%.

When the monitored slurry pressure, impeller rotation torque, and vibration intensity reach their respective warning threshold values, the corresponding warning function is triggered.

For example, when the monitored slurry pressure exceeds 70% of the preset pressure threshold value, a slurry pressure warning signal is issued to alert operators that the slurry pressure poses an abnormal risk requiring timely investigation and resolution.

Further, while determining whether relay pump 2 has malfunctioned based on the monitored slurry pressure, impeller rotation torque, and vibration intensity, the method further comprises:

Taking a second preset percentage of the preset pressure threshold value, preset torque threshold value, and preset vibration threshold value as the respective alarm threshold values for slurry pressure, impeller rotation torque, and vibration intensity.

Wherein the second preset percentage is greater than the first preset percentage.

Specifically, the second preset percentage may be 90%.

When the monitored slurry pressure, impeller rotation torque, and vibration intensity reach their respective alarm threshold values, the corresponding emergency alarm function is triggered.

For example, when the monitored vibration intensity exceeds 90% of the preset pressure threshold value, a vibration intensity alarm signal is issued to alert operators that the vibration intensity is abnormal and that a fault involving stones entering the pump body or becoming lodged in the impeller is imminent, prompting operators to investigate and resolve the abnormality to prevent relay pump 2 from malfunctioning.

Further, after determining that relay pump 2 has malfunctioned, the method further comprises:

Activating a high pressure flushing device to inject high pressure water toward the first connecting pipe, the second connecting pipe, and the pump body inlet and the bottom of the pump body of relay pump 2, so as to flush the slurry inside the first connecting pipe and the second connecting pipe, as well as the slurry at the impeller, inlet channel, and bottom of the pump body of relay pump 2.

Specifically, after relay pump 2 malfunctions, flushing with high pressure water can remove deposits from the first connecting pipe, the second connecting pipe, and the interior of relay pump 2, improve the flowability of the internal slurry, and resolve the problem of slurry blockage.

Further, before the shield machine pipe replacement zone reaches the installation position of relay pump 2, the method further comprises:

Pre-casting the internal structural lining of the tunnel, compactly filling the box culvert, and constructing an installation base 28 at the installation position of relay pump 2.

Wherein the installation base 28 is used to secure relay pump 2.

Specifically, after the shield machine trolley has cleared the area where relay pump 2 is to be pre-installed, the internal structural lining of the tunnel is pre-cast, the box culvert is

compactly filled, and an installation base is constructed at the installation position of relay pump 2; at the same time, the connection structure is pre-embedded, and the installation of relay pump 2 can only proceed once the strength of the cast structure meets the design strength requirements.

Further, before incorporating relay pump 2 into the slurry pipeline system, the method further comprises:

Commissioning relay pump 2 to ensure its normal operation.

Specifically, after relay pump 2 is installed at the designated position, the first connecting pipe and the second connecting pipe are arranged; during installation, the pipelines are first pre-assembled and subsequently reinforced by welding; during this period, shield machine tunneling and commissioning of relay pump 2 may proceed simultaneously.

Commissioning of relay pump 2 consists of two parts: local control commissioning and communication and remote control commissioning. During the commissioning phase, all performance parameters of relay pump 2 must be tested to ensure that each component functions normally.

For example: 1. After power supply is connected, first check whether the indicator lights on each component and panel are functioning normally. If any abnormality is found, investigate the cause and resolve it immediately.

2. Test whether the rotation direction of the drive motor fan and the shaft seal water pump is correct; after confirmation, disconnect the coupling between the drive motor and the slurry pump, and test the rotation direction of the drive motor. At this time, the local/remote selector switch may also be tested simultaneously to verify its normal operation, as well as the interlock start capability of the slurry pump.

3. Set the parameters of the frequency converter according to the functions to be implemented, including acceleration time, deceleration time, low-speed frequency, high-speed frequency, and other parameters.

After the commissioning of relay pump 2 is completed without issues, adjust each gate valve to incorporate relay pump 2 into the slurry pipeline system for operation.

Further, after incorporating relay pump 2 into the slurry pipeline system, the method further comprises:

When performing fault maintenance on relay pump 2, open the main control switch and close the first switch and/or the second switch.

In the embodiment of the present invention, taking a target tunnel as an example, the total length of the target tunnel is 6,270 m, the shield machine excavation diameter is 14.57 m, the tunnel structure outer diameter is 14.0 m, the inner diameter is 12.8 m, the segment thickness is 0.6 m, the effective clear area above the rail surface is 83.79 m², the tunnel adopts a single-bore double-track cross-section without partition walls; longitudinal through-rescue passages with a width of 1.25 m and a height of 2.2 m are provided on both sides; stairways with a width of 0.8 m are provided at 150 m intervals along the longitudinal direction of the tunnel, connecting the vehicle travel area and the under-rail escape passage. To reinforce the primary segment lining structure and enhance the waterproofing, fire resistance, impact resistance, and corrosion resistance of the lining structure, a 300 mm secondary lining is provided in the tunnel. The rock strata through which the tunnel shield machine primarily passes include silty clay and fine rounded gravel, with localized interbedding of silty clay or fine sand, slightly weathered tuff, and slightly weathered tuffaceous lava. A total of 505 m consists of slightly weathered rock with an average strength of 33 MPa to 54 MPa, accounting for 8%; 433 m consists of soft-upper/hard-lower strata, accounting for 7%; and 5,332 m consists of soft soil strata, accounting for 85%. After shield machine launching, tunneling begins at a gradient of -20‰ over 2,137 m with a vertical height of 42.74 m; then continues at a gradient of -6.5‰ over 900 m with a vertical height of 5.85 m; and subsequently at a gradient of 3.3‰ over 3,233 m with a vertical height of 10.67 m.

Based on the actual site conditions combined with the flow rate and head of the slurry pumps, a total of 4 slurry feed pumps and 6 slurry discharge pumps, totaling 10 units, are required for this section. Using the existing construction method to install the relay pump requires a total of 70 days of machine downtime, which has a significant impact on the construction schedule and labor costs.

By contrast, using the relay pump installation and slurry discharge method during shield machine tunneling as provided in the embodiment of the present invention, the pipeline connections of the pump during the installation process do not affect the normal tunneling operations of the shield machine, enabling relay pump installation to proceed simultaneously with tunneling.

When the relay pump malfunctions and maintenance is required, simply closing the first switch and/or the second switch and opening the main control switch ensures normal tunneling operations of the shield machine, reducing operational efficiency constraints on tunneling caused by shield machine equipment failures.

By applying the relay pump installation method of the present invention within this construction section, the construction schedule can be effectively shortened by more than 70 days, labor costs reduced, and construction efficiency improved.

In actual application, the method for relay pump installation and slurry discharge during shield tunneling provided by the embodiments of the present invention requires no stoppage of shield tunneling operations: after the shield pipe replacement zone reaches the relay pump installation position, the cover plate at the opening of the first branch pipe is replaced via the first switch, and the cover plate at the opening of the second branch pipe is replaced via the second switch; subsequently, the first branch pipe is connected to the slurry inlet of the relay pump via the first connecting pipe, and the second branch pipe is connected to the slurry outlet of the relay pump via the second connecting pipe; opening the first switch enables communication between the first branch pipe and the slurry inlet, opening the second switch enables communication between the second branch pipe and the slurry outlet, and simultaneously closing the main control switch incorporates the added relay pump into the slurry pipeline system, thereby achieving relay pump installation during ongoing shield machine tunneling operations, saving construction time and improving construction efficiency.

The relay pump installation and slurry discharge method during shield machine tunneling of the present invention can significantly shorten the tunnel construction schedule and, during

subsequent construction, can effectively prevent shield machine stoppages caused by equipment failures, thereby ensuring that the tunnel construction schedule is not affected while maintaining safe and civilized construction practices.

In the relay pump installation and slurry discharge method during shield machine tunneling of the present invention, after the relay pump is incorporated into the slurry pipeline system, a pressure gauge is provided at the inlet of the relay pump to monitor the inlet slurry pressure in real time; a torque meter is provided at the motor shaft of the relay pump to monitor the impeller rotation torque within the relay pump; and an accelerometer is provided on the pump body of the relay pump to monitor the vibration intensity during relay pump operation. Whether the relay pump has malfunctioned is determined based on the real-time monitored slurry pressure, impeller rotation torque, and vibration intensity against the corresponding preset threshold values; if relay pump malfunction is detected, the main control switch is opened and the first switch and/or the second switch are simultaneously closed, switching to the main slurry pipe for slurry delivery; after relay pump maintenance is completed, switching back to the relay pump branch for slurry discharge; throughout the entire process, the shield machine does not stop, ensuring the construction efficiency of the shield machine.

The above descriptions represent only specific embodiments of the present invention, but the scope of protection of the present invention is not limited thereto; any changes or substitutions within the technical scope disclosed by the present invention shall be covered within the scope of protection of the present invention. Therefore, the scope of protection of the present invention shall be determined by the scope of the claims.

Claims

1. A relay pump installation and slurry discharge method during shield tunneling, characterized in that it comprises:

in conjunction with the pre-determined relay pump installation position, when constructing the slurry pipeline system, a branch slurry pipe is used at the said relay pump installation position; the branch slurry pipe comprises a main slurry pipe assembled from two slurry pipes with Y-shaped branches, with the joints of the two slurry pipes connected via a main control switch; a main control switch is provided at the middle of the main slurry pipe, together with a first branch pipe and a second branch pipe communicated with and disposed on the main slurry pipe; the first branch pipe and the second branch pipe are disposed opposite each other on the two sides of the main control switch, and the openings of both the first branch pipe and the second branch pipe are sealed with blind plates;

the angles between the first branch pipe, the second branch pipe, and the main slurry pipe are each 25° – 35° , and the lengths of the first branch pipe and the second branch pipe are each 70–90 cm;

before the shield pipe replacement zone reaches the relay pump installation position, advance casting of the tunnel internal structural lining is performed, box culverts are filled and compacted, and an installation base is constructed at the relay pump installation position; the installation base is used to secure the relay pump;

after the relay pump is installed to the set position, the first connecting pipe and the second connecting pipe are arranged; during pipe installation, pre-installation is performed first followed by reinforcement welding at a later stage, during which shield tunneling and commissioning of the relay pump can proceed simultaneously;

after the shield pipe replacement zone reaches the relay pump installation position, the first switch and the second switch are used to replace the blind plates at the openings of the first branch pipe and the second branch pipe respectively; the first branch pipe is connected to the slurry inlet of the relay pump to be installed via the first connecting pipe, the second branch pipe is connected to the slurry outlet of the relay pump via the second connecting pipe, and the relay pump is incorporated into the slurry pipeline system; the first switch is used to control the communication between the first branch pipe and the first connecting pipe, and the second switch is used to control the communication between the second branch pipe and the second connecting pipe;

the first connecting pipe comprises a first bent section and a first straight section; the

relay pump is disposed below the branch slurry pipe, the slurry outlet is disposed at the top of the relay pump, and the slurry inlet is disposed on the side wall of the relay pump; one end of the first bent section is connected to the first branch pipe, the other end of the first bent section communicates with one end of the first straight section, the other end of the first straight section communicates with the slurry inlet, and the angle between the first straight section and the horizontal plane is -15° to -20° ;

the second connecting pipe comprises a second bent section and a second straight section; one end of the second bent section communicates with the slurry outlet, the other end of the second bent section communicates with one end of the second straight section, one end of the second straight section is connected to the second branch pipe, and the angle between the second straight section and the horizontal plane is 30° – 40° ;

the first bent section and the first straight section are connected via a flexible pipe, and the second bent section and the second straight section are connected via a flexible pipe;

a pressure gauge for monitoring slurry pressure is provided at the inlet of the relay pump, a torque meter for monitoring the impeller rotation torque within the relay pump is provided at the motor shaft of the relay pump, and an accelerometer for monitoring the vibration intensity during operation of the relay pump is provided on the pump body of the relay pump;

based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity, determining whether the relay pump has malfunctioned; upon determining that the relay pump has malfunctioned, opening the main control switch, closing the first switch and/or the second switch, and switching to the main slurry pipe for slurry discharge operations.

2. The method for relay pump installation and slurry discharge during shield tunneling according to claim 1, characterized in that the determining whether the relay pump has malfunctioned based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity specifically comprises: determining whether the relay pump has experienced a blockage fault based on the relationship between the monitored slurry pressure and a preset pressure value, and the relationship between the monitored impeller rotation torque and a preset torque value; determining whether the relay pump has experienced a fault of stones being mixed into the pump body or stones being jammed in the impeller based on the relationship between the monitored vibration intensity and a preset vibration value.

3. The method for relay pump installation and slurry discharge during shield tunneling according to claim 2, characterized in that, while determining whether the relay pump has malfunctioned based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity, the method further comprises: taking a first preset percentage of the preset pressure value, the preset torque value, and the preset vibration value as the warning threshold values for the slurry pressure, the impeller rotation torque, and the vibration intensity, respectively; upon the monitored slurry pressure, the impeller rotation torque, and the vibration intensity each reaching the respective warning threshold values, triggering the corresponding warning function.

4. The method for relay pump installation and slurry discharge during shield tunneling according to claim 3, characterized in that, while determining whether the relay pump has malfunctioned based on the monitored slurry pressure, the impeller rotation torque, and the vibration intensity, the method further comprises: taking a second preset percentage of the preset pressure value, the preset torque value, and the preset vibration value as the alarm values for the slurry pressure, the impeller rotation torque, and the vibration intensity, respectively, wherein the second preset percentage is greater than the first preset percentage; upon the monitored slurry pressure, the impeller rotation torque, and the vibration intensity each reaching the respective alarm values, triggering the corresponding emergency alarm function.

5. The method for relay pump installation and slurry discharge during shield tunneling according to claim 1, characterized in that, after determining that the relay pump has malfunctioned, the method further comprises: activating a high pressure flushing device to inject high pressure water toward the first connecting pipe, the second connecting pipe, and the pump body inlet and pump body bottom of the relay pump, so as to flush the slurry inside the first connecting pipe and the second connecting pipe, as well as the slurry at the relay pump impeller, inlet channel, and pump body bottom.

6. The method for relay pump installation and slurry discharge during shield tunneling according to claim 1, characterized in that, before incorporating the relay pump into the slurry pipeline system, the method further comprises: commissioning the relay pump to ensure

normal operation of the relay pump.