Design of a New Type of Rake Suction Dredger System Based on Adaptive High Pressure Water Cutting

Shihao Wang⁎, Sicheng Li¹, Shiqiang Jing¹

¹School energy and power engineering, Wuhan university of technology, Wuhan, Hubei, 430063, China

⁎Corresponding author’s e-mail: 1169155440@qq.com

Abstract: China has a vast sea area and many rivers and lakes, so waterway dredging, environmental protection dredging and water conservancy dredging have a large market. Excellent ship type development, power plant, dredging machinery, auxiliary equipment, integrated monitoring and other energy-saving emission reduction technology development and application, not only for dredging enterprises to save energy, but also to reduce emissions caused by environmental pollution, access to economic and environmental protection double benefits. With the sustained and steady growth of China's economy, the rapid development of the shipping industry has led to the development of port infrastructure and waterway dredging and other projects, so that the domestic demand for dredging machinery and equipment also tends to flourish, dredger as the main dredging equipment has a broad market.

1. Introduction
With the sustained and steady growth of China's economy, the rapid development of the shipping industry has led to the development of port infrastructure and waterway dredging and other projects, so the domestic demand for dredging machinery and equipment also tends to flourish, and dredger as the main dredging equipment has a broad market. With the rapid progress of port construction at home and abroad, the maintenance and dredging of Port pool channel has become the primary problem that all ports must face. There are many kinds of dredger, according to the difference of dredger working mechanism, which can be divided into rake suction dredger, grab bucket dredger, chain bucket dredger, rake suction dredger and bucket type dredger five kinds.

After years of steady development, the technical content and equipment performance of Harrow suction ship have been greatly improved, but with the expansion of the application field of dredging engineering, the construction water environment of rake suction dredger has become more and more complex, the construction condition is not limited to conventional dredging, often encountered special working conditions, and its construction requirements have been gradually improved. It is necessary not only to achieve high construction efficiency, but also to meet the requirements of refined environmental protection dredging operations.

2. Material and Methods

2.1. Optimal design of Rake head

2.1.1. Improved cutting Force analysis
The cutting force has an important influence on the production efficiency of the rake suction dredger, which is mainly affected by three aspects, such as the speed of dredging, the width of the rake head and the depth of dredging. The choice of dredging speed must take into account the propulsion power of the ship, the safety of the operation and the safety of the equipment. Excessive speed will cause the rake tube to float upward under the water flow force and reduce the cutting depth, but reduce the concentration of dredging. There is an optimal ratio between the width of the rake head and the diameter of the rake tube in order to obtain the optimum flow state in the rake head, and to take into account the range that can be reached by the vacuum in the rake head, in practice, the width of the rake head cannot be increased arbitrarily because of the ship scale limit. Therefore, increasing the cutting depth becomes the only alternative path. This project designed the high-pressure water gun system, through the high-pressure water gun will be deposited at the bottom of the mud sand cutting, to deepen the cutting depth, optimize the cutting force of the purpose.

2.1.2. Removable rake teeth and adjustable beams
Because the rake teeth are directly rubbed against the mud surface, we design detachable rake teeth to replace the worn tooth tip in a timely manner, and the beams that are fitted with rake teeth also use an adjustable structure of bolted joints, and the staff can adjust the position before and after the rake teeth according.

2.2. Control and installation of high pressure water gun system

2.2.1. Design of high pressure water gun
Water gun Cutting is a powerful cutting flow, cutting material, which is formed by the combination of high pressure flow and the metering sand transported by the sand conveyor pipe.

Because the flow of water ejected from the nozzle will form a conical cone, it is necessary to determine the diameter and flow rate of the nozzle according to the distance between the nozzle and the flushing surface and the soil quality. The jet flow rate of conical-straight nozzle is extremely uniform and concentrated in both direction and size, and its injection efficiency is the highest, so the conical-straight nozzle is selected as the type of high pressure flushing nozzle with serialized rake head.

Nozzle plate, anti-wear plate installed on the outside of the high-pressure water gun, it is possible to contact with the underwater mud surface, so that it is subjected to friction. The use of high wear-resistant materials, but can not be welded, the use of weldable materials are not wear-resistant. Through the data access we learned that for this reason, the wear-resistant materials Mn13 and ordinary steel plate cast together composite materials, both wear-resistant, but also can be welded, installation process is simpler, easy to install and disassemble.

The high pressure water gun plays an important role in the dredging work. First of all, in the complex and uncertain waters environment need to consider the overall sealing of water gun, to prevent the cessation of work midway, affecting the implementation of dredging. Secondly, the power of the water gun needs to be adjusted, in the face of different soil to modify the parameters of the water gun, set the appropriate cutting depth, to achieve energy saving and emission reduction effect.

Through the study of the existing rake suction dredger, we find that the loading concentration of the dredger is not high, in large part because the cutting depth of the rake head is not enough. Based on this problem, we designed to attach two high-pressure water cannons to both sides of the rake head. Through the drive of the hull, the effect of edge cutting edge rake mud is realized. The high pressure water gun is used to cut two ditches on the mud surface on both sides of the rake head, reduce the adhesion between the soil, enhance the loosening capacity of the rake head, and improve the dredging efficiency.

3. Results
In line with the principle of energy saving and emission reduction, this project optimizes the rake head and water gun components of the rake suction dredger without making large-scale changes to the existing dredger. The following are the most important innovations and advances.
3.1. Design of cutting riverbed on both sides of high pressure water gun.
The current rake suction dredger is often because of the hard soil of the riverbed, in the mechanical rake suction process, the rake head rake the mud layer is shallow, which leads to the low concentration of mud inhaled by the suction pump, the water quality of the basin is cloudy, two times the pollution problem is serious. A high-pressure water gun system located on both sides of the rake head based on this design can alleviate this problem to some extent. As the dredger moved, the high-pressure water gun cut two mud trenches on both sides of the rake head. In the process of rake head rake digging mud layer, between the existing two mud trenches, rake excavation resistance decreased, rake digging depth increased.

3.2. Adaptive system of high pressure water gun based on terrain and soil conditions.
In the process of the rake head moving, the water gun easily crashes into the hard riverbed, damaging the high-pressure water gun device. The adaptive device of the high pressure water gun can monitor the depth of the underwater mud layer in real time, so that it is in the best position with the surface of the mud layer, which not only ensures the best depth of cutting, but also prevents the collision of high pressure water gun. Adaptive systems can also automatically determine whether to use high-pressure water cannons by monitoring soil quality, ensuring maximum energy efficiency.

3.3. Replaceable rake tooth design.
Through the analysis of river basin data of different soil quality, the replaceable rake teeth made of different materials are selected to minimize the abnormal loss of rake teeth caused by different material of rake teeth.

4. Discussion

4.1. Analysis of high pressure water gun

4.1.1. Effect of sand flow in water gun liquid on cutting effect
The high pressure water flows through the nozzle into the mixing chamber and establishes a local vacuum zone in the mixing room, which can inhale the measured sediment through the conveyor tube and then combine with the water to establish a powerful sand cutter cutting flow. If the sand flow control is not appropriate, it will obviously affect the cutting effect. When the sand flow is too large, the nozzle is easy to clog; Sand flow over the hour cutting force decreased, cutting difficulties.

4.1.2. Deep analysis of high pressure water gun cutting
A large number of studies have shown that when other conditions are the same, the flow of water punches objects at different impact angles without lateral movement and will get different cutting depths. And when hitting an object vertically, the depth of cutting is greatest. As the impact angle gradually deflects to the level, the cutting depth will gradually decrease. This situation is mainly due to the increase of the impact angle to aggravate the reflection of the jet, thus reducing the impact capacity of the jet. Therefore, the high pressure flushing with vertical angle is used as the research object to analyze its groundbreaking depth.

The cutting depth of high pressure water gun is mainly affected by three aspects of nozzle transverse velocity, jet speed of nozzle outlet and critical jet velocity. The test proves that if the nozzle has a certain transverse speed, even if the transverse speed is very small, the groundbreaking depth will be greatly reduced. The transverse movement of the nozzle greatly shortens the time of Jet liquefaction, which leads to a significant decrease in the depth of the groundbreaking.

The jet velocity of the water gun has a maximum groundbreaking depth value, because with the increase of jet impact time, pressure water will be clustered at the bottom of the groove, these pressure water will cause the incident hydraulic attenuation until the maximum groundbreaking depth is reached, so the growth rate of scour depth decreases gradually with the increase of jet impact time.
4.2. Adaptive control system of high pressure water gun
Aiming at the complex water environment, we design an adaptive plc control system, which achieves the goal of adaptive complex waters by automatic control of water gun. The adaptive system first monitors the hardness of the mud layer in the waters and determines whether the use of high-pressure water gun auxiliary operation. When the high pressure water knife operation is opened, the adaptive system automatically recognizes the height of the underwater mud surface, thus adjusting the height of the gun, so as not to cause damage to the water gun, at the same time to cut the mud surface to the maximum extent, to reduce the difficulty of rake head rake mud, to reduce the effect of energy consumption.

5. Conclusion
The rake suction efficiency is improved, the mud compartment space is saved, and the energy consumption is reduced accordingly. In this design, the high pressure water gun can be cut directly to the hard substrate, to a certain extent, which solves the traditional rake suction dredger for the hard substrate cutting difficulties, easy to leak excavation and low efficiency problems. Direct block inhalation avoids mixing large amounts of water into the parabolic area and affects yield. The improvement of efficiency has largely saved energy consumption.

The overall cutting of the new rake suction dredger system has the advantages of environmental protection, energy saving and high efficiency. Compared with the traditional rake suction dredger, it has reduced fuel consumption in the whole construction cycle of dredging soil, small displacement, more in line with the green economic theme, and application limitations are small. The energy saving and emission reduction effect is significant.

References
[1] Zhu,F. (2018) Improvement of dredging equipment for modern rake suction dredger. China Equipment Engineering 2018 Phase 2nd P57-58 1671-0711
[2] Wang,Y.L, Li,Y, Shen,J.Q. (2017) Journal of Shanghai Jiaotong University 2017 volume 51st 3rd P305-307 1008-7095
[3] Li,L.(2018) Let water cutting technology play a more efficient role in the Chinese market Hyundai Manufacturing 2018 Issue 16th P16 1671-9395
[4] Wei,T.X, Wang G. (2018) Water cutting route based on Computer aided design Machinery Manufacturing 2018 Volume 56th, phase 6th P73-74 1000-4998
[5] Xue, S.X, Han Yahong, Li Yue (2014) Research on current water cutting technology Fluid Machinery 2014 Phase 12th p52-54,67 1005-0329