DEVELOPMENT AND APPLICATION FOR MOBILE EMERGENCY DRAINAGE SYSTEM IN URBAN FLOOD RESCUE

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Abstract

In order to solve the urgent needs of large-flow persistent water supply and drainage equipment for emergency rescue of urban flood and firefighting, the vehicle-mounted emergency water pipeline system is developed. The systems consist of two basic units, which are pump station vehicle and flexible pipeline operating vehicle. The pump station vehicle is used for water drawing and pressurized transport in the field. The flexible pipeline operating vehicle is used for pipeline storage, development and fold. The systems can reach the max flow rates of 1500m3/h, and the transport distance can reach as far as 2000m. The mechanized rapid development and wrap of large-caliber flexible pipeline is designed. The system can be used independently as well as combined. The use of vehicle-based integration, pipeline mechanized development, automatic station laying and operation scheduling, lightweight floating water pump and other comprehensive technical means significantly increases the operation efficiency and mobility of the system. A production base is built in Hubei 3611 Mechanical Co., Ltd in China to achieve industrialization. The system is sold to more than 30 provinces and cities in China, and has played important roles in many major disaster rescue tasks in recent years.

Keywords: emergency flood control and drainage in cities, urban flood disaster rescue, drainage system for long distant, emergency rescue

Introduction

China is the country with the most serious natural disasters in the world. Floods and waterlogging have always topped all kinds of disasters, regardless of their extent and losses. With the global climate change, waterlogging frequently occurs in Chinese cities, with more and more impacts and heavier property losses. It has become a normal reality threat faced by many cities, such as the "July 21" torrential rain in Beijing in 2010 and the Shouguang flood in Shandong in 2018. Foreign rescue practice shows that the emergency water delivery equipment system, which can be rapidly maneuvered, deployed and put into operation, is an important technical means to deal with major fire and explosion accidents and urban waterlogging disasters. Large flow and long-distance continuous water supply guarantee plays a great role in improving rescue efficiency. As early as 2005, China

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imported some HFS equipment from Holland Haichuang Company, which played an important role in the rescue of oil pipeline fire and explosion accident at Dalian New Port in 2010. For this reason, with the support of scientific research projects such as the National Science and Technology Support Plan and Chongqing Science and Technology Public Relations Plan, researchers have been tackling key problems for seven years. They took the lead in developing a three-type mobile urban large-flow emergency water supply and drainage equipment system in China, which consists of three basic modules: pump station vehicle, soft pipeline operation vehicle and automatic hydraulic station distribution and operation dispatching system.

1 Development objectives and ideas

In order to meet the special application requirements of emergency rescue, the research goal of "quick operation, reliable adaptation, module combination, economy and efficiency" has been established. Around the development goal, on the basis of in-depth analysis of functional requirements and the existing technical level, the overall design idea of "matching on demand, module combination, function integration, overall management and control" is put forward.

To achieve the goal of "quick operation", four problems need to be solved. First, it can maneuver itself and does not rely on external transport capacity. The equipment system shall be integrated on an independently equipped carrier platform, independent of external transportation equipment or hoisting equipment, and transported by all-vehicle mobile mode or integrated self-loading and unloading mode. Second, soft pipelines can be quickly deployed and withdrawn. According to preliminary technical analysis, to reach the rated throughput of type 3 equipment and ensure economic throughput, the required pipeline diameter should reach 300 mm. The deployment and collection of large-diameter soft pipelines is labor intensive and takes a long time to deploy, which is not suitable for the needs of emergency rescue. Mechanized deployment and withdrawal are needed to develop corresponding technical equipment. Third, water can be drawn quickly. The system has a large conveying flow rate, with the minimum flow rate reaching 750m3/h. The conventional self-priming pump has limited self-priming height and long operation time. It is necessary to develop a portable special water intake pump, which can be quickly thrown to the water intake surface by manpower or throwing devices. The fourth is to carry out hydraulic design quickly. The traditional method of measuring topographic parameters by manual instruments and then carrying out hydraulic calculation should be changed to greatly increase the preparation time for transportation. Advanced technical means such as satellite positioning are used to measure terrain parameters, and the hydraulic parameters of different conveying conditions, different terrain conditions and different equipment systems are calculated quickly through a software system, so that the pump station position and operation parameters when multiple pump stations are operated in series can be quickly determined.

To achieve the goal of "reliable adaptation", four problems need to be solved. One is to adapt to the field environment, mobile equipment has a certain cross-country mobility and good traffic capacity, according to the needs of the application environment, the upper part should adapt to different transport chassis or cross-country chassis. Second, the water intake device can adapt to the surface water intake environment. Water intake equipment has strong anti-impurity capability, shallow water intake performance and self-adaptation to water level changes. Third, it will not affect the deployment of other on-site rescue equipment as much as possible. In the area where the equipment is deployed, the normal operation of other rescue and support equipment shall not be affected, for example, the necessary pipeline crossing protection equipment shall be equipped, and the road passage of other rescue equipment shall not be affected. To ensure the safety of personnel working in the water environment, safe and reliable power equipment shall be adopted and corresponding hydraulic drive systems shall be developed. The fourth is to reduce the failure rate and improve the recovery ability of the failure. Technically mature and reliable power devices, transmission devices and water intake and pressurization devices are adopted to reduce intermediate links and fault sources. The system can quickly adjust the operation parameters according to the change of the task throughput, and can quickly adjust the operation parameters during the off-station transportation under fault conditions.

2 Overall composition

The system consists of different number of pump station vehicles and pipeline operation vehicles. Under the condition that terrain elevation difference is not considered and rated transportation flow is satisfied, type DN 300-I, DN 300-II and DN 300-III equipment can be freely combined and transported to the required distance. Within this distance range, according to actual needs, with the support of hydraulic distribution station and operation dispatching system, the conveying distance can be reduced to overcome the height difference, or the conveying distance can be reduced to increase the conveying flow.

2.1 Pumping Station Vehicles

Taking the integral self-loading and unloading mode and the dual-engine structural form as examples to illustrate.

Figure 1: Integrated multifunctional pump station vehicle (integral self-loading and unloading type)

The pump station truck is composed of an integral self-loading and unloading truck and a pumping station loading shelter. The integral self-loading and unloading truck can be used as a public transportation platform for the shelter.

- Pumping station shelter

The square cabin of the pump station includes a water pump unit, a pressurized pump unit, accessories on board, etc. The pump unit consists of engine, hydraulic system and floating pump. Pressure pump unit engine, clutch, pressure pump, pipeline and other components; Accessories on board include emergency plugging equipment, tents, filter screen cleaning tools, hydraulic winches, water bladders, etc. Schematic diagram of pumping station shelter structure is shown in Figure 2.

Figure 2: Pumping station shelter

- integral self-loading and unloading vehicle

Take the self-loading chassis refitted from Dongfeng DFL3258 as an example. It is mainly composed of automobile chassis, self-loading and unloading system, truck-mounted crane assembly and apron assembly, etc. It is used for transportation and fast loading and unloading of pumping station shelter. The self-loading and unloading system adopts the telescopic arm type, adopts full hydraulic drive, and is installed on the chassis girder of the automobile through the subframe. It is equipped with lifting arm, telescopic arm and supporting roller, etc. Through lifting oil cylinder, telescopic oil cylinder and supporting oil cylinder, the top can be turned over, telescopic and supported, and the loading and unloading process can be completed. The front of chassis girder and the rear of cab are equipped with truck-mounted crane assemblies for lifting operations. The maximum working radius of the truck-mounted crane is 3m, and the maximum lifting weight at 3m is 350kg.

2.2 Pipeline Deployment and Collection Vehicle

DN300 - Ⅰ, DN300 - Ⅱ and DN300 -Ⅲ are the same types of pipeline deployment and collection vehicles. Taking Dongfeng DFL3258 automobile chassis as an example, the pipeline extension and retraction operation vehicle chassis, power take-off, hydraulic system, hose winder head, pipe arrangement device, hose box, control system, etc. are composed. DN300 soft pipeline for carrying 2000m is used for automatic deployment and withdrawal of the pipeline, as shown in fig. 3.

Figure 3: Pipeline deployment and collection vehicle

The main technical indexes of the pipeline deployment and collection vehicle are shown in Table 1.

Table 1: of Pipeline Deployment and Collection Vehicle

No.	Parameter	Value
1	dimensions	≤12000mm×2500mm×3700mm
2	curb weight	≤25000 kg
3	laying speed	≤45 km/h
4	withdrawal speed	≤2.5 km/h
5	maximum winding traction force	2500 N
6	pipeline diameter	Φ300 mm
7	hose length	2000 m
8	joint type	Plug-in type
9	working temperature	-25℃ ～ +46℃

2.3 DN300 -Ⅱ

DN300 - Ⅱ is operated by force taking, hose operating head and manual stacking. The pump station vehicle and the operation vehicle are integrated into a comprehensive function vehicle.

2.4 DN300 -Ⅲ

DN300 -Ⅲ adopts the whole vehicle transportation mode, and adopts the scheme of parallel water intake with double pumps, pressurization with single pump and double-line transportation. The chassis engine takes power to drive the hydraulic system. The hydraulic system drives two floating pumps to take water. After being pressurized by one pressurizing pump, the water is transported to the disaster relief site beyond 6km through double pipelines to realize long-distance water supply. As shown in fig. 4.

Figure 4: Illustration of DN300 -III

The integrated multi-function pump station is composed of a water intake pump unit, a pressurizing pump unit, on-board accessories and a chassis. The water take-off pump unit consists of chassis engine power take-off, hydraulic system, floating water take-off pump, hydraulic hose winding device, etc.The pressure pump unit consists of engine, clutch, pressure pump, process system, etc. Accessories included emergency plugging equipment, tents, filter screen cleaning tools and water bags.

3 Key Technologies

3.1 Equipment Modular Assembly and Application Technology

Through in-depth analysis of different kinds of disasters, rescue needs and rescue forces, three basic modules, namely pump station truck, soft pipeline truck, automatic hydraulic station distribution and operation dispatching system, were constructed, which improved the universality, interchangeability of water and the ability of combination and application of equipment systems. The pump station truck is a special module, which determines the transportation flow of the equipment system. Soft pipeline operation vehicles, automatic hydraulic distribution stations and operation dispatching systems belong to common modules and are suitable for different equipment systems. Under the command and coordination of the dispatching system, independent operation of a single pump station and series operation of multiple pump stations can be realized by assembling different numbers of pump station vehicles and soft pipeline operation vehicles, thus forming water supply and drainage systems with different transportation flows and further transportation distances, and meeting the emergency rescue needs of multiple disasters, stages and forces. The developed three-type vehicle-mounted equipment system realizes the vehicle-mounted mobility, assembly and application, rapid deployment, rapid operation and automatic dispatching of long-distance soft pipeline system. Foldable and flattened flexible polyurethane pipelines are adopted, with conveying flow rates of 750m3/h, 900m3/h and 1500m3/h, conveying distances of 6000m, 1000m and 6000m, and maximum field water intake height of 20 m.

3.2 Vehicle-mounted large-caliber soft pipeline automatic winding, automatic pipe arranging and rapid docking technology

The equipment system adopts DN300 polyurethane soft pipeline with the largest diameter in China at present. It is difficult to recycle it by manpower when there is more water in the connection hose connector and pipe. An uninterrupted soft pipeline recovery technology based on toothed belt transmission is invented. Innovative hose winding technology based on full-size double friction roller drive, hydraulic drive head lifting, alignment and recovery technology, developed an integrated winding mechanism and applied it to the first generation of equipment. The invention discloses a two-degree-of-freedom cabin automatic pipe arranging technology relying on pipeline gravity. The technology of winding and arranging pipes based on double-sided multi-roller drive and integrating winding and arranging pipes in the cabin is innovated, and an integrated mechanism winding and arranging pipe device is developed and used on the second generation of equipment. Through continuous technological innovation, the problems of automatic traction of large-diameter soft pipelines, positioning of winding machine heads, emptying of hoses and barrier-free passage of joints have been solved. The developed integrated discharging and winding mechanism has completely changed the current situation of relying on manual pipe laying both at home and abroad. The number of hose winding workers has been reduced from 3-5 to 1, and the pipe laying in the cabin is completely unmanned, thus greatly reducing the labor intensity of workers and improving the operation safety and withdrawal speed. The hose deployment speed is over 10km/h, the withdrawal speed of the first generation equipment is over 2km/h, and the withdrawal speed of the new generation equipment is over 3 km/h.

3.3 Reasonable Dynamic Pressure Distribution and Load Balance Based on Satellite Positioning Hydraulic Station Distribution and Operation Scheduling Technology

Using GNSS (Global Navigation Satellite System) positioning chip on the mobile terminal, which supports GPS, BDS, GLONASS and other systems, combined with CORS (Continuous Operation Reference Station System) in the region or network, high-precision and accurate data of the line can be quickly obtained, providing basic data for pipeline hydraulic station distribution and operation scheduling. Fully considering the characteristics of soft pipelines such as small elastic modulus and large diameter change under internal pressure, a new nonlinear dynamic hydraulic friction algorithm for soft pipelines is innovated and applied to hydraulic gradient calculation, crossing point judgment, large drop section disposal, pump station number and arrangement calculation, etc. to improve the accuracy of hydraulic station distribution and operation scheduling. Innovating the technology of hydraulic station distribution and operation dispatching, it has realized that the pumping station does not suffer from under-pressure at the entrance, over-pressure at the exit, dynamic pressure stability of the line and optimal operation of multiple pumping stations, thus ensuring the safe and stable operation of the equipment system. When the task throughput of the equipment system changes or the pump station is shut down for some reason, a new operation scheduling scheme can be rapidly formed to ensure the reliable operation of the equipment system. The satellite positioning technology, positioning-based service (LBS), automatic hydraulic station distribution based on reasonable dynamic pressure and load balance, and operation scheduling technology are integrated into a whole, which solves the problems of automatic location of pumping stations, automatic generation of scheduling schemes and rapid adjustment of operation parameters under different equipment systems, different terrain conditions and different transportation flows, greatly improves the operation speed of equipment systems, and improves the informatization and intelligence level of hydraulic station distribution and operation scheduling.

3.4 Large Flow Floating Water Intake and Delivery Technology in Field Environment

The developed floating high-flow water intake technology has broken through the key technical problems of anti-field water source impurities, anti-water source corrosion, shallow water, adaptive water level change and light weight of the device. Two types of aluminum alloy high-flow floating water intake pump and its protective components have been developed. The vertical water intake height is more than 20 meters, which is more than 3 times higher than the self-suction height of conventional self-suction centrifugal pumps. The pump body has a mass of 75kg and can be transported to the water surface by manpower. The hydraulic drive system of floating pump, the automatic winding mechanism of hydraulic hose and the hoisting mechanism of floating pump are developed. The length of hydraulic hose is 60m, and the horizontal water intake distance is 45m or more, which improves the safety of water operations and the speed of unfolding and withdrawing, reduces the operation time of the system, and meets the needs of different use environments.

4 Industrialization and Application

The mobile emergency drainage system for large-flow cities has been industrialized in Xinxing heavy industry Hubei 3611 machinery co., ltd. two production bases for emergency drainage systems have been built in Wuhan and Xiangyang, Hubei, with three production lines. the products have been sold to more than 30 units in more than 10 provinces such as Beijing, Tianjin, Shanghai, Chongqing, Shaanxi and Hubei. On April 6, 2015, a fire and explosion occurred in Zhangzhou Gulei PX Project; on April 9, 2015, a fire broke out in Cangzhou Guofu Wholesale Market; on July 16, 2015, a fire and explosion occurred due to the leakage of a hydrocarbon spherical tank in Shandong Rizhao Shida Science and Technology Petrochemical Company; on August 12, 2015, an explosion occurred in Tianjin Binhai New Area; on August 2016, a flood disaster occurred in Wuhan; on August 2018 and 2019, a flood disaster occurred in Shandong Shouguang. In 2019, major fires and explosions such as the "March 21" Xiangshui chemical enterprise explosion in Yancheng, Jiangsu, and emergency drainage and emergency rescue played an important role, providing a new means for emergency rescue and disaster relief, saving people's lives and property losses, and achieving remarkable social and economic benefits.

Figure 5: Shandong Shouguang drainage rescue

Conclusion

With the rapid development of China's economy and society, the acceleration of industrialization and urbanization, the increase in urban population density, the increasing load on urban infrastructure, and the increasingly serious impact of floods on cities. Urban waterlogging has become a real threat and persistent disease faced by most cities. It is difficult to eliminate it through large-scale infrastructure construction in the short term. Mobile emergency drainage system for large-flow cities is of great significance for reducing the impact of waterlogging disasters in Chinese cities at present and in the future, reducing disaster losses and ensuring the orderly operation of cities, with significant social benefits. The system is a large emergency equipment set, which is an important part of the development of emergency industry encouraged and supported by the state. It is conducive to promoting the transformation and upgrading of traditional industries and the cultivation of emerging industries, with obvious direct economic benefits.

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