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Design of all-around automatic integrated rail cleaning vehicle

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Abstract: With the vigorous development of rail construction in China, the workload of rail cleaning increases rapidly. The use of automatic machinery for rail cleaning will become a trend. The market needs to meet the needs of rail cleaning vehicles' high reliability and high efficiency. Based on the market demand, this paper designed and developed a high-efficiency, energy-saving, cost-effective rail cleaning equipment. The cleaning operation vehicle integrates the function of pollution absorption, cleaning and high-pressure water. It adopts advanced technology such as artificial intelligence and automatic control system to realize the functions of automatic train operation, route planning, operation state monitoring, water level control, fault detection, garbage classification, operation and maintenance modular management, etc. At the same time, for the high humidity working environment, the function of waterproof has been taken into consideration.

1. Introduction

With the development of new rail transit represented by subway and tram, it is crucial to keep the equipment clean in the subway tunnel for the normal use, maintenance and safe operation of the subway train. At present, there are many researches on highway tunnel cleaning technology in China. However, the cleaning of the subway tunnel has not been paid attention to, and the domestic research and use are in the early stage [1]. The current subways are basically underground tunnels, so the dirt produced during the operation will gradually accumulate and be difficult to discharge. The most serious pollution is the dust produced in the air circulation operation [2].

At present, there are two main ways to clean track in China: using rail cleaning engineering vehicle, that is, driving special equipment vehicle with simple washing function to clean track, manual

cleaning. At present, most of the clean rail cars on the market are washed by fixed high-pressure spray gun, which can not clean some dead corners of the tunnel, and reduces the washing effect. What's worse, the manual cleaning method is not only inefficient, but also faces the threat of running trains in the tunnel.At present, this kind of product is in the initial stage of R & D and manufacturing, which have the disadvantages of the complex structure, high cost and large maintenance workload.

2. Structural design of rail cleaning vehicle

Based on the existing problems, this paper designed the cleaning operation vehicle, which integrates pollution absorption, cleaning and high-pressure water, and is efficient, reliable and safe. Modular design facilitates maintenance of equipment. The whole car consists of No.1 and No.2, which can be seen in Figure. 1. It is composed of sprayer, pump group, brush unit, dirt box, air filter unit, vacuum unit and a water tank. A sprayer located at the front end of the vehicle can intelligently switch 20 bars, 80bar of two grades of pressure water according to the adhesion of the attachment, which is used to clean the rail, track bed and tunnel sidewall respectively. The central brush unit and the side brush unit located in the middle of No.1 vehicle is driven by a hydraulic pump station and are used to clean the central and bilateral areas of the line respectively. The cleaned dirt is inhaled into the dirt box by the vacuum unit through the brush unit. The water supply of the whole vehicle is provided by the water tank located on the No.2 vehicles. The sewage tank is equipped with an air diaphragm sewage pump for pumping a large amount of sewage from the tunnel sewage well and collecting it into the box.

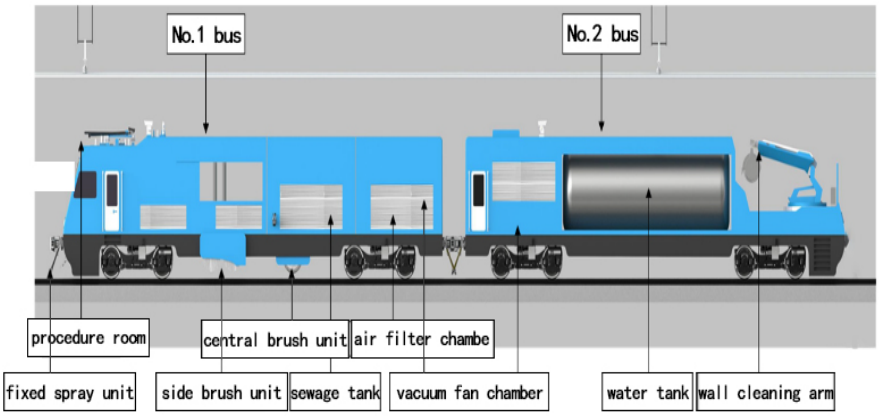

Figure. 1 Schematic diagram of the designed rail cleaning vehicle

2.1 Design of the high-pressure water system

The most important part of the rail cleaning vehicle is the cleaning module. Two different washing structures are designed for the tunnel wall and the roadbed track surface. At the same time, it can expand the washing range, enhance the washing effectively and improve the washing efficiency. The principle is shown in Figure.2.

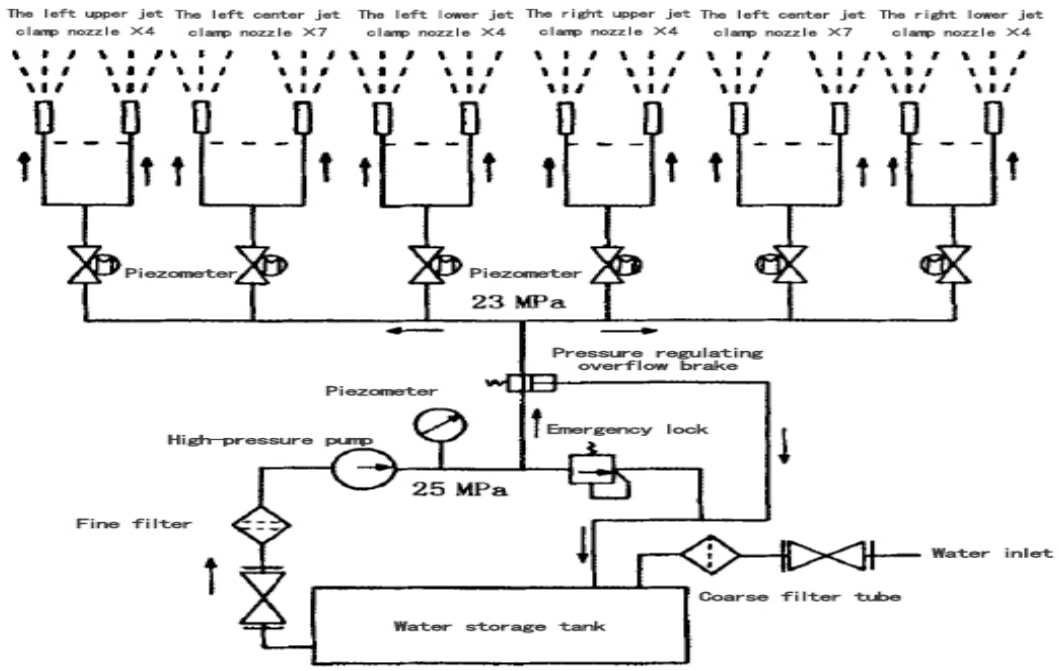

Figure. 2 Schematic diagrams of the high-pressure water system

2.1.1 Spraying devices

The spraying device of No.1 cleaning vehicle is placed in front of the frame, which reduces the formation of water mist and improves the visibility of the tunnel line during the operation of the rail cleaning vehicle. The high-pressure pump converts normal pressure water into high-pressure water. The pump for cleaning vehicles is a piston pump. Solenoid valve controls waterway break, to achieve automatic control.

In order to avoid the electrical equipment in the washing operation, a special shape washing module is designed in the No.1 car spraying frame. In order to ensure the strength of the whole structure, two supporting rods are welded to avoid the risk of water leakage caused by welding hinges directly on the water pipe. Left and right flushing module structure avoids 1300~1 500mm of electrical equipment, by washing the upper part of the tunnel wall of electrical equipment, letting the flow through the electrical equipment, and avoiding electrical equipment damp short circuit.

2.1.2 High-pressure water jet systems

A total of 3 sets of the high-pressure water jet system are installed.

The first group is equipped with a low-pressure cleaning nozzle device at the front end of the cleaning vehicle, which is equipped with eight 23500-1/4 type low pressure (20 bar) nozzles, each of which is about 2 L/min. These nozzles provide lower pressure to clean the dust of the trackbed.

The second group of high-pressure cleaning sprinkler heads, with 10 23500-1/5 high-pressure (80 bar) nozzles, each with a water supply of about 6.4 L/min, is used to remove sediment around the roadbed and at the drain, while washing the grease and iron chips of the fasteners. The vacuum unit will collect the washed water, scattered sediment and other washed dirt.

The electromagnetic valve for monitoring each water distribution system, all nozzles and nozzles are made of stainless steel. Moreover, the water flow is monitored by a flow switch to detect whether the nozzle is blocked by sand. The pressure sensor is installed on the high-pressure side to ensure the continuous strength of the nozzle under the unstable water quantity. Two spraying systems can be controlled independently.

The flow rate is 102 L/min. The pressure is 15 MPa, and the frequency conversion motor with the power of 30 kW is used.

2.2 Design of vacuum suction system

According to the dust theory, the wind speed in the suction port and pipeline should be greater than its suspension speed to absorb the dirt. When the particle size is small, the starting speed of different dust particles does not change much, which indicates that the size, shape and density of dust particles have little effect on the starting speed. The starting speed is mainly determined by van der Waals force, which is mainly related to the diameter and spacing of particle size. As the diameter of the particle becomes larger, the influence of gravity becomes larger and larger. When the diameter of the particle is larger, the van der Waals force becomes smaller. The wind speed of the suction port is 30~40 m/s.

3. Optimal treatment of the rail cleaning vehicles

The air volume of the traditional cleaning vehicle suction device is large, and the noise is high. The airflow from the exhaust fan will form dust and endanger the health of the construction personnel. At the same time, tunnel ventilation fan and exhaust fan work together to cause resonance, affecting tunnel stiffness and track fastness. Therefore, reducing noise is very necessary.

HQ tube is to achieve the purpose of silencing by the elimination interference of coherent sound waves in a certain space region. As shown in figure 3, at the branch point of the supervisor and the side pipe, HQ pipe the pipe noise acoustic wave into two channels. When the two branch sound waves with different propagation distances (acoustic path difference) meet at the confluence, the sound waves of a specific frequency will interfere with each other and cancel each other out.

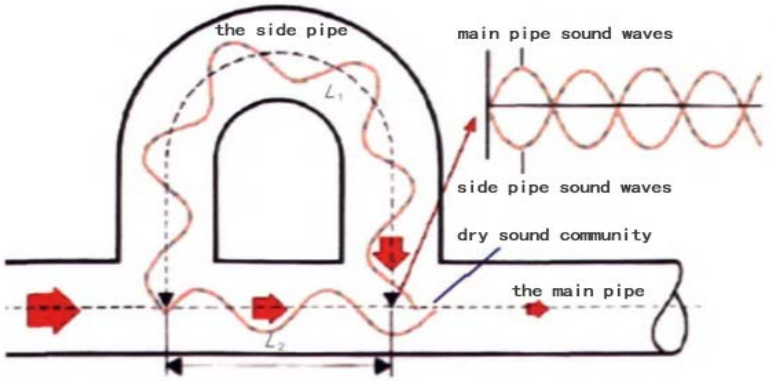

Figure. 3 Principle and characteristics of HQ tube silencing

4. Design of an automatic control system for the rail cleaning vehicle

The automatic control system of rail cleaning vehicle monitors, controls and adjusts the train operation status based on the actual situation of a train running on the line. It is divided into three parts: ground equipment, vehicle part and remote equipment.

At present, the cleaning vehicle controlled by ground equipment needs all the basic data, and the vehicle part is processed by the transmitted signal, thus forming the relevant control data.

The automatic control system of the rail cleaning vehicle is designed as following. The system is divided into three modules: the rail cleaning vehicle's function module, the rail cleaning vehicle's operation management module, and the rail cleaning vehicle's system management module Rail cleaning vehicle operation module and rail cleaning vehicle operation management module are the core modules of the automatic control system.

5. Conclusion

In order to ensure the cleaning of the subway tunnel, this paper designs an all-round automatic integrated rail cleaning vehicle with the functions of pollution absorption, cleaning and high-pressure water, which has the characteristics of high efficiency, reliability and safety. Modular design is adopted, and maintenance is convenient. The proposed operation line planning, operation status remote monitoring and automation perfectly solve the problem of long rail cleaning operation time, effectively improving the degree of automation, safety, and reliability of the cleaning operation.

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