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Structural design of heavy floating garbage cleaning robot suitable for small water area

Wencheng Wang[1,2,*], Pengcheng Zhang[1,2], Tianci Liu[1]

[1]Department of Mechanical Engineering, Hebei University of Water Resources and Electric Engineering, Changzhou, 061000, China
[2]Hebei Industrial Manipulator Control and Reliability Technology Innovation Center, Changzhou, 061000, China
[*]Corresponding author: 576869677@qq.com

Abstract: *The garbage on small water areas such as parks, lakes and urban rivers is mainly divided into lightweight floating garbage such as garbage bags and leaves and heavy floating garbage such as tires and animal carcasses. The garbage cleaning robot designed in this paper is mainly used to cleaning heavy floating garbage. This paper introduced in detail the structural design process of the garbage cleaning robot, including the design of the hull, the cleaner, the pushing device and the calculation of related parameters.*

Keywords: *garbage cleaning robot, heavy floating garbage, small water area, structural design*

1. Introduction

In recent years, the problem of garbage pollution in Chinese waters has become increasingly serious. There is more and more floating garbage in rivers, lakes and other waters. With the development of time, these floating garbage will first pollute the ecological environment of the water body, and then threaten the life and health of nearby residents. At present, the surface garbage cleaning mainly uses large ships, which cannot adapt to the garbage cleaning of small rivers, especially for the cleaning of heavy floating garbage, which is still manually cleaned. Therefore, aiming at the problem of cleaning up small surface heavy floating garbage, a surface garbage cleaning robot is designed to realize the collection and transfer of surface heavy garbage.

At present, the research technology of surface garbage cleaning device suitable for large water bodiesis is mature, and it has multiple series, and has become the main equipment to protect the urban water environment. The Trash Cat series surface waste cleaning device developed by UMI adopts catamaran type and is equipped with twin propeller propulsion[1,2]. The Dolphin multi-functional ecological cleaning ship developed by GLOBECO, an Italian company, has the functions of oil leakage, large garbage collection, chemical spill collection, water oxidation treatment, detection and fire protection[3]. The SOLID series of cleaning boats provided by the Spanish Beach-Trollers company adopt a single vessel, with independent manipulators fixed on both sides of the bow, and the front end of the manipulators installed with nets respectively. After appropriate adjustment of the attitude of the manipulators, the nets can flexibly salvage the surface garbage [4,5]. The WEEDCAT multi-functional ecological cleaning ship produced by MAVI DENIZ Environmental Services in Turkey uses catamarans and is mainly used for cleaning floating organisms and floating pollutants in waters such as lakes[6]."Qingpiao 1" is mainly used to clean up a large number of floating objects on the water surface of the Three Gorges Reservoir area[7]."Century Light" is a new type of surface cleaning working vessel controlled by embedded technology and powered by electric propulsion system [8]."Luqing Haijie" is mainly used for cleaning floating garbage in the sea area of Qingdao Olympic Sailing Base. The main feature of the ship is the tipping device inside the ship, which can collect garbage while sailing or stationary[9].

To sum up, the existing research mainly focuses on large water area garbage cleaning equipment, and there are few researches on small water area floating garbage cleaning equipment, so the research content of this paper has practical engineering application value.

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2. Structural design

The structure of the designed cleaning robot is shown in Figure 1, where 1 is the hull, 2 is the hull connection device, 3 is the pushing device, 4 is the bow, and 5 is the cleaner.

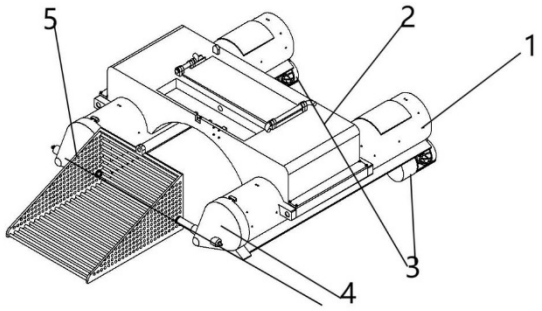

Figure 1: Structural of heavy floating garbage collection robot

2.1 Structure design of robot hull

The hull adopts double hull structure and aluminum alloy 6061 material, taking into account the overall buoyancy and draft depth of the hull. The hull adopts the structure supported by the hull keel, and the main design parameters include: length L, draft depth d, hull width b, total displacement Δ, and sheet width b_1

When designing the hull length L of the robot, Froude number Fr can be used to express the influence of the captain on the speed, and its expression is as follows:

$$F_r = \frac{v}{\sqrt{gL}} \tag{1}$$

Where v—Robot speed, m/s,v=1 m/s;

L—hull length, m.

The low speed catamaran drifter Froude number is 2.2. The hull length L can be calculated to be 2.1 m.

The selection of draft is mainly considered from the depth of channel and the principal scale coefficient b/d. The width-draught ratio b/d of the clear robot body ranges from 1.67 to 3.33. The width of the sheet has been determine as 0.35m; Choose a moderate slice width to draft ratio 2, It can be calculated that the robot hull draft d is 0.18 m.

Hull aspect ratio range is L/b=6~8.75; Considering that the operating environment is small water area with small wind and waves and little operation intensity, Therefore, the value L/b=6 is feasible, and the calculation can be obtained: b= 0.35m.

According to the draft depth, the volume of the hull underwater cleaning robot is 0.24456m³, and the volume of the bow underwater is 0.01854m³. Then the total displacement Δ can be calculated as 0.2635 m³.

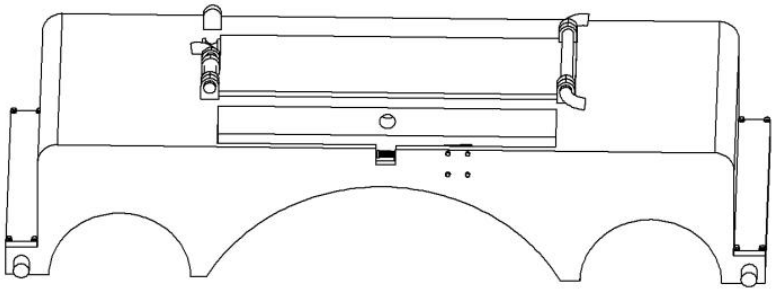

Figure 2: Structural of robot hull connection device

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2.2 Structure design of robot hull connection device

The robot hull connection device is located in the behind of the two hulls, which plays the role of stabilizing the position of the hulls and maintaining the distance between the hulls, which is shown as Figure 2. The weight of the hull is increased, so that the hull reaches the correct water intake and ensures the normal work of the cleaning robot. The material of choice for the hull connector is polypropylene.

Since the control device of the robot is located on the hull connection device, the corresponding coordination and connection are configured on this device.

(1) There are circular arch holes on the left and right sides of the hull connector device, which are used to cooperate with the hull and are used to distinguish the direction of the bow and stern position of the hull.

(2) Above the connecting device, there are two compartments, one of which is closed and the other is open. The closed compartment is used to place the control circuit board and power line. The closed cabin is closed by a cover, which is designed to be fitted with a latch in order to facilitate the easy opening and closing of the cabin. The bottom of the cover is a convenient rotation of the shaft and the hole, the front is a latch and a jack, in order to prevent the latch from falling and rotating, in its two end positions are provided with a baffle and a slot for stabilizing the latch.

The open cabin is mainly used to house the axis motor and the spool. The spool is placed in the central position of the connector device, and the central position of the hull connection device has an opening for the spool to match with the spool to facilitate the connection of the spool and the cleaner device.

(3) Both sides of the hull connection device are spring-type push rods for hull connection, which are matched with the two holes on the outside of the hull. Since the push-rod device does not need to be modified frequently, the device is fitted with bolts and threaded holes, and this fit is an interference fit. Because the force required by the bolt connection is not large, it meets the strength requirements of the bolt and connector, so it is not checked.

The push rod is matched with the outer hole of the hull, the push rod is pushed inward, the spring is compressed and contracted, and the push rod is withdrawn inward. At this time, the push rod is placed at the outer hole and the outer hole. The thrust is removed due to the force of the spring and the push rod is ejected outwards and stuck in the outer two holes of the hull. In order to facilitate disassembly, the holes on both sides of the hull are open, and the push-rods are external.

(4)The spool motor is located on the inner wall of the open cabin in front of the connector device, and is fixed with bolts and nuts. Because the motor and spool parts are small and the motor power is small, the speed requirement is not high, so the motor and the spool are matched with the groove between the two axes.

2.3 Structure design of robot cleaner

The robot cleaner designed in this paper is shown in Figure 3. The cleaning device designed is a bucket lifting, and the bucket lifts the floating objects and carries them to the shore.

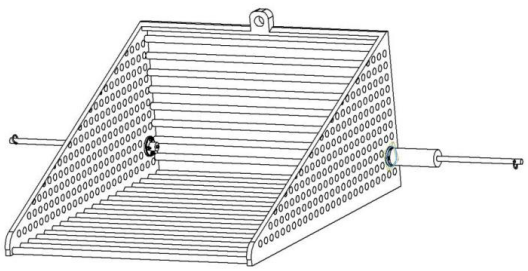

Figure 3: Structural of robot cleaner

When working, the cleaner is partially submerged in water. Before the floater enters the cleaner, the front end of the cleaner is lower than the bottom of the floater. The hull is controlled to align with the floater, move forward to collect the floater inside the cleaner, and the spool motor is controlled to collect the floater until the front end of the cleaner higher than the water surface. The robot only needs

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to control the floater in the cleaner, push it back to shore and recover it, saving energy consumption.

2.4 Structure design of robot pushing device

Robot pushing device is a device that provides power to the robot. As shown in Figure 4, a propulsion device is arranged behind the hull, and the steering operation of the robot can be realized through the speed difference between the two propulsion devices.

The garbage collection robot designed in this paper has small structure size, slow operation and small working environment, so the resistance of the robot hull mainly includes: flow resistance and airflow resistance.

The wind speed is set to level 3, when the wind speed is 8m/s, and the time t=1 s, the cross-sectional area is 0.5723 m^2, and the wind resistance F can be calculated by the momentum conservation formula:

$$Ft = mv \tag{2}$$

The wind resistance can be calculated F=47.28 N.

The water resistance is about 800 times the wind resistance, and the cross sectional area of the robot in the water is A=0.11664 m^2.

Simulated wind resistance F_1 was used to solve the problem, and the simulated wind resistance speed was set to be 1 m/s, which was the same as the robot's traveling speed.Using formula 2, the simulated wind resistance can be obtained as F_1=0.1515 N, and the water resistance can be obtained as 120.4 N.

The total resistance of the garbage collection robot during operation is 167.68 N.

Therefore, robot pushing device chooses the motor model 57BL95S15-230TFA, whose voltage is 24V, speed is 3000rpm, and power is 150W.

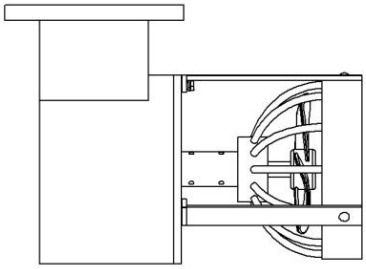

Figure 4: Structural of robot pushing device

3. Conclusion

This paper mainly introduces the structural design of garbage collection robot, which mainly includes hull, hull connection device, cleaner and pushing device. cleaner is a shovel type device at the bow of the robot, connected by a separate motor and pulling wire, which is easy to control and easier to clean up garbage. The shovel-type device is partially submerged and partially above the surface, so that the heavy garbage is still in the water after entering, the water part restricts the location of the garbage, and the water still provides buoyancy for the garbage, and only a small push is required to bring the garbage back to the shore when the garbage is collected. The pushing device is two propellers under the hull, each controlled by a separate motor, to better achieve forward, backward and turn, easy to operate.

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