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Research Overview of Amphibious Platform Driving Device

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Abstract. Amphibious vehicles are mainly equipped with water driving devices on the land driving system, which can be divided into caterpillar type, propeller type, water-jet type and air-jet type. The universal drive mode avoids two sets of devices and is simple in structure. The rotating surface vector thruster is designed to drive the amphibious platform in an amphibious way, which can sail from the water to the water. On the basis of this, the impeller driven device of baffle plate is subtracted from hub, and the baffle is added to reduce weight and improve efficiency.

1. Introduction

China is one of the countries with the largest number of rivers and lakes in the world. There are more than 1,500 rivers with a drainage area of more than 1000km2, more than 2,800 lakes with an area of more than 1km2, and more than 100 coastal bays [1]. People from different ethnic groups live in these drainage area. With the development of society, people's demand for water and land transportation is getting higher and higher. The amphibious platform can improve the efficiency of people's water and land transportation and reduce traveling time. The amphibious platform based on the basilisk lizard can meet people's needs. The basilisk lizard can crawl on the ground through the movement of the foot and can also run fast on the surface of the water. This unique athletic ability provides inspiration for the research of new propulsion technology for amphibious platforms.

2. Development overview

2.1. Foreign overview

In 1883, MreTyrr designed foot amphibious vehicles AmphiiboustTicycle. This amphibious vehicle is obtained by dismantling the pedal tricycle and then reassembling the canvas. It looks like a boat. In 1894, Baech & Harris introduced the CyoleRaft amphibious vehicle [2]. This car is actually a bicycle with two inflatable buoys. Both of these amphibious vehicles were built on the basis of a bicycle, and were the first exploration of amphibious vehicles.

Table 1 List of amphibious vehicles in various countries

time	country	model	speed	propulsion mode
1920	United Kingdom	D	2.4km/h	crawler
1932	Soviet	T-37	6km/h	propeller
1942	Japan	Camisa	9.6km/h	propeller
1943	United States	LVT4	10km/h	crawler
1947	Soviet	ПТ-76	10km/h	water jet propulsion
1997	United Kingdom	Aquada	48km/h	water jet propulsion
2004	Switzerland	Splash	80km/h	propeller
2004	United Kingdom	Humingda	70km/h	Jet Propulsion
2009	Switzerland	Squba	6km/h	jet drive
2013	United States	Jaguar	72km/h	jet drive

Among them, the driving device of the amphibious vehicle mainly relies on the chain transmission of the bicycle to drive the wheel, the human being occupies a large component, the mechanical degree is not high, the structure is complicated, and the utility is not strong.

In the 20th century, countries have paid more and more attention to the research of amphibious vehicles. The table shows the development history of amphibious vehicles developed by various countries.From Table 1, according to national amphibious vehicle propulsion development can be divided into crawler, propeller, water -jet propelled and jet-propelled.

At the beginning, designers from various countries developed a crawler-type amphibious vehicle, which relied on crawler water skiing and was mainly used for landing. The speed in the water was not high. In 1943, the United States launched the LVT4 amphibious vehicle on the basis of LVT2 and LVT3. It uses W-shaped cast aluminum crawling track, which affects the vehicle's driving on land [3]. Then there was a propeller-type amphibious vehicle. In 1932, the Soviet T-37 amphibious reconnaissance tank was an earlier propeller-type amphibious vehicle with a water speed of 10km/h [4].

Fig. 1 Splash

Fig. 2 Jaguar

In 2004, Rinspeed launched the high-speed amphibious vehicle Splash. It uses a natural gas twin-cylinder turbocharged engine [5]. On the land, Splash is driven by rear-wheel drive, while in the water it is driven by a three-bladed propeller at the rear of the vehicle.

In general, the Splash propellers are simple in construction and inexpensive, meeting the needs of the masses. And Splash's natural gas engine is less polluting. The use of hydrofoil can reduce water resistance. The hydrofoil relies on the Z-type drive to achieve up and down movement of the propeller, which can save space. However, the use of the hydrofoil reduces the reliability of the amphibious vehicle, especially when it is driven in shallow water.

In 1947, Soviet engineer developed the ПТ-76 amphibious tank which is the first tank to use water jet propulsion technology.

In 1997, the British company GIBBS developed the amphibious vehicle Aquada. Aquada relies on waterjets to sail at speeds of up to 48km/h. The water jet propeller can be divided into three parts: inlet pipe, propulsion pump and steering device [6].

Aquada's speed is high, but the water jet propeller is complex and expensive. Aquada uses the technology of wheel retraction so it can sail like a boat. In places such as wetland tidal flats, it can cause problems when driving.

In 2004, the British GIBBS company launched the Humingda high-speed amphibious vehicle. When driving in the water, Humingda can transfer power from the wheels to the jet propulsion system. Humingda is more practical than Aquada and has a wider range of activities.

In 2009, Rinspeed Automotive Design Company developed the Squba diving concept car [7]. The car relies on an electric motor to drive the rear wheels and produces propulsion from two propellers at the rear of the car and two jet drives at the front. There are jets on both sides of the body, and the curved tubular thrusters on both sides of the fender control the submerged direction.

Squba can travel on land, water and underwater, greatly expanding the range of vehicles. Unfortunately, the vehicle only considers the resistance of the air, and does not consider the resistance of the water. As a result, the maximum underwater speed is only 3km/h.

In 2013, WaterCar Corporation of California developed the Jaguar amphibious vehicle [8]. It is driven by a jet propeller and can enter the water directly from the land. However, it must have sufficient initial speed before entering the water to ensure that the vehicle can sail normally.

Recently, the Nizhni Novgorod Technical University of Germany developed the ZVM-2901 screw propulsion car, which uses the rotor-screw propeller drive [9]. This spiral propulsion car can travel in snow, swamps, beaches, and jungles. The spiral drum is hollow, which can reduce the weight of the whole vehicle and provide buoyancy.

The ZVM-2901 screw propulsion car has good environmental adaptability. Unfortunately, it will cause damage to the road surface when driving on ordinary roads, and the thread on the spiral drum will wear out for a long time.

2.2. Domestic overview

Domestically, research on amphibious platforms is later than abroad. After years of development, domestic research has made great progress. After 2000, there have been more and more innovations in drive devices in China.

In 2002, Qiu Zhizhen of Anhui University of Technology designed the walking paddle wheel drive. The main body of the device is a rotating sliding rod mechanism, which is composed of a sliding rod wheel, a roller, a sliding sleeve and a sliding groove. The sliding sleeve can slide over the slide bar. When the sleeve is in contact with the ground in turn, the device produces a walking motion [10].

The walking paddle wheel is suitable for uneven road surface, which can reduce the amplitude of the wheel core up and down. However, only 8 points of the walking paddle wheel contact the ground. It is less than the wheel carrying capacity. Because of the discrete structure, when the walking paddle wheel encounters an impact load, only one sliding sleeve is subjected to the load; the car wheel is a continuous structure that can bear a load on a small plane. Therefore, the car wheel is better than the walking paddle wheel.

In 2005, Beijing University of Aeronautics and Astronautics proposed a propeller propulsion system [11]. The system is combined into a wheel shape by the blade structure, and the blade is opened into a paddle shape for water stroke during navigating. This system combines wheels and blades, simplifying the mechanical structure, reducing costs and improving water and land conversion efficiency. Not only that, the paddle system can climb over some small pits and has a certain ability to overcome obstacles.

In 2009, Shenyang Institute of Automation proposed an integrated amphibious robot with wheel and leg [12, 13]. This device is a mixture of drive wheels and propellers with a curved structure at the end of the propeller. The device is divided into two parts, front and rear, which are linked by flexible joints to achieve crawling and swimming movement. Among them, 13 motors drive 6 wheel paddles to complete the crawling movement of hexapod insects. The movement of the water can be realized by the Wheel paddle which can be used as a propeller, and the flexible joint and the front joint of the flexible joint control direction.

The robot has the characteristics of small size, flexible movement, good environmental adaptability and strong obstacles. It can travel in swamps and beaches. However, the robot also has the characteristics that the joint structure is complex, the drive motor is many, the control is difficult, and the mechanical fault is easy to appear.

In 2013, Cheng Long of Harbin Institute of Technology proposed a paddle wheel propulsion mechanism [14]. This mechanism places the Dynamic Seesaw Bright wheel on the inside of the car wheel, causing the Seesaw to rotate with the wheel. The driving device on the road surface is a wheel tire, and the driving device on the water surface is a moving wheel. The mechanism has the characteristics of variable water inlet angle, high water-skiing efficiency, and no conversion driving mode between water and land. Institutions can be used in swamps, coastal environments, etc.

In 2016, Gao Kang of Shanghai Ocean University designed a planetary Dynamic Seesaw Bright wheeled amphibious robot. It can use a paddle wheel to complete a series of movements such as forward, backward, and turn in water and on land [15].

In 2011, Chinese female university student Zhang Yuhan designed the Aqua amphibious concept car [16]. The Aqua is based on hovercraft technology and is driven by an electric motor. A set of engine-driven impellers provides lift and a set of drives at the rear of the car completes propulsion and steering. The Aqua amphibious concept car can travel on terrain such as roads, water and ice. Aqua uses hydrogen fuel cells to reduce environmental pollution.

3. Progress of this topic

As can be seen from the previous section, the development of amphibious platforms at home and abroad has yielded results, but there are still deficiencies. The research group proposed a water surface vector thruster that mimics the Basilisk Lizard walking on water. This device can be used for underwater navigation to the surface of the water.

Unlike the lighter-weight insects, the basilisk lizard swings the two hind legs at a suitable angle, allowing the body to lift upwards and forward to achieve water walking. Its water walking speed can reach 1.5 m/s, and the walking distance per second is about 10 times of the length [17].

When the basilisk lizard runs at high speed, there is a great interaction between the liquid and the sole of the foot. This interaction helps the basilisk lizard to run on the surface. Such a mechanism provides a theoretical basis for proposing a new type of amphibious drive.

For the study of the Basilisk Lizard running on the water, Steven Floyd designed the four-legged water robot walking mechanism. The four-bar mechanism simulates the leg movements of the basilisk lizard. The angle between the sole and the calf of the robot is constant, and the water inlet angle of the sole is fixed, so the whole movement process of the basilisk lizard is not really simulated [18].

Li Bing and Xu Linsen designed a drive mechanism based on a planar linkage [19]. The mechanism is driven by a motor and the speed of the entire process remains the same. This mechanism is a simplification of the movement of the basilisk lizard, with a light and simple structure.

Fig. 3 soles of the feet

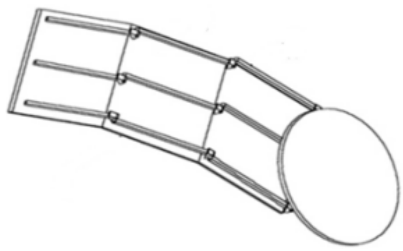

Fig. 4 Baffle vane type

In 2012, Cai Shuwen of Shanghai University designed the soles of the feet to simulate the movement of the basilisk lizard [20]. This ulti-section hinge structure is joined by a plastic sheet and the ends are connected by disk surface. It uses a motor to connect the crank rocker mechanism to drive the ball-like foot movement. This kind of sole is naturally flexible, and the contact between the sole of the foot and the water is achieved by controlling the contraction of the sole of the foot. However, this joint of the foot relies on the overall drive, and there is no independent driving torque for each joint. If it is in the vertical state, the sole of the foot may not be reset.

Under the background of the mechanism of the water surface of the basilisk lizard, the research team analyzed the relative motion trajectory of the ankle. During the exercise cycle, the feet of the basilisk lizard rotate nearly 180°relative to the water surface, and the ankles move in an elliptical shape. If the foot plane of the effluent recovery stage is converted forward to the rear, the underwater trajectory of the ankle is approximately semi-circular. The motion trajectory can be completed by a rotational motion. On this basis, the research team designed a rotary water surface vector thruster consisting of a hub, spokes, telescopic rods and blades [17]. It uses the blades to continuously slap the water at high speed, producing upward lifting force and horizontal propulsion. As the impeller speed increases, it produces a solid-liquid force that increases. The whole device is lifted out of the water surface and enters the sliding state, avoiding the resistance wall and reducing the water resistance.

Now, the research team has improved the hub type into a baffle vane type. The wheel spokes are omitted, the baffle is connected to the blades, and the vane propulsion device is designed. The baffle can be perforated and this design reduces weight throughout the unit. Not only that, the baffle can play a certain gathering effect when the blade hits the liquid, so that the device can drive forward better.

4. Conclusion

The baffle-blade drive is still in the model phase, and the model is not actually used in practice, but it is still in the experimental phase.

In order to improve the model, it is necessary to enlarge the experimental device to prepare for the next water experiment. Moreover, the baffle type device is a drainage type drive, and if it is desired to increase the speed, it can be converted to a water-skid type drive.

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