Design of 360° moveable and uniform feeding system

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Abstract. In order to solve the feeding problem in shrimp aquaculture which is high labor intensity, low automation and non-uniform feed distribution, a 360° moveable and uniform feeding system was proposed. The feeding system uses turbine worm mechanism to realize the quantitative feeding, and the turbine is conveying plate which can adjust the conveying speed according to catamaran’s cruise speed. Casting plate can achieve 360° uniform cast feed. A catamaran is used as carrier platform for feeding machine, and BeiDou satellite positioning system installed on the catamaran helps to automatic cruise. So the moveable and uniform of shrimp pond feeding can be realized in this way.

1 Introduction

Most of existing feeding machines are shore-based feed casting machines, which is used for fixed-point fish feeding. The fish in the pond will swim to the area near to the feeder when it begins to feed. Fish farming machine mainly use screw conveying or shaking methods to control feeding speed, and use high speed rotating plate to feed out[1,2]. Because Shrimp’s activity range is smaller than fish’s, so the fixed-point feeding is not suitable for shrimp. The typical shrimp feeding method is artificial feeding. Workers walk around the pond and casting the feed. The artificial feeding can’t promise to distribute the feed evenly, which will affect the feeding efficiency.

Xundong Wu [3] invented the automatic shrimp pond feed casting device, which uses a shore based motor to drive the cableway which is installed in shrimp pond and control the casting device working path. The cableway can pull the floating base of casting device and control feeding speed at the same time. XiaoLong Chen and Jun Chen[4], they developed a boat-based feeder to imitate artificial feeding around shrimp pond. The feeder was placed on the catamaran, and the catamaran was guided by the cableway installed around shrimp pond. They can guarantee the feed casting machine to work around shrimp pond in this way. The two methods mentioned above can take the place of artificial work and realize mobile and automatic feeding for shrimp aquaculture. But both of them need to install cableway or traction rope on the shore to guide feed casting paths, so the work route is not flexible, and guide paths are also affected by shrimp pond geographical position.

In order to realize the mobile and uniform shrimp feeding, A 360° moveable and uniform feed casting system[5] is designed.

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2 The structure and working principle of the system

2.1 Structure of the system
The feeding system can divided into two parts, catamaran and feed casting machine. Catamaran mainly includes the hull, propeller, the protect cover of propeller and a BeiDou hardware system. Feed casting machine mainly consist of feed container, feed conveying mechanism, feed casting mechanism and machine control box. The feed casting machine is placed on the catamaran, which is shown in figure 1.

2.2 Work principle of system
This system can feed on a preset path or designated areas according to our requirement. Generally, shrimp pond feeding route is around the shrimp pond and in the area that 1.5 meters to 4.5 meters from the shore, so the entire width of the feeding route is about 3 meters, so we need feed casting machine accurately casting the feed to the area within 3 meters width of the feeding routes. When we use a designated area feed casting model, catamaran travels to a specified location to cast feed. In this model, we achieve uniform feed coverage from near to far by changing the motor speed. A shrimp pond can be divided into multiple points to cast the feed. Catamaran cruise to each point to complete quantitative and uniform feed casting. The feed casting system working parameters are shown in table 1.

| Number | Parameters         | Values     |
|--------|--------------------|------------|
| 1      | Machine weight     | 30Kg       |
| 2      | Feed container capacity | 70L       |
| 3      | Transfer motor power | 15w       |
| 4      | Max feeding speed  | 6Kg/min    |
| 5      | Cast motor power   | 40w        |
| 6      | Max casting radius | 9m         |
| 7      | Propeller power    | 100w/pcs   |
| 8      | Battery            | 50Ah       |
| 9      | Cast plate high    | 350mm      |
| 10     | satellite position | < 1m       |

When catamaran cruises according to the preset trajectory, feed casting machine works at a certain area. The feed leak out from container mouth to fill the conveying plate gaps, worm drives conveying plate to rotate 180 °, then the feed will be sent to casting plate's inlet mouth. The feed leak out from casting plate feed inlet mouth to rotating casting plate, and the feed will be accelerated by casting plate and casted out around. Feed casting machine structure is shown in figure 2.

We can ensure the feeding speed matches catamaran cruise speed by changing the conveying motor speed to control the feeding speed. The feed will be cast out when the catamaran finishes cruising shrimp pond. Rotational speed of the casting motor is controllable, so we can set different speed according to the different feeding distance, which can adapt to different casting objects and the environment.
3 Design of the conveying mechanism

A worm gear is used to drive conveying mechanism to convey the feed. Conveying plate outer ring is designed as a worm gear, which has six split layers to form a closed feed storage space between upper and lower splint. To avoid the situation that the feed is compacted to solid in the process of worm gear rotating and can’t freely fall from the feed storage space, we design a push feed spring above the casting plate’s inlet mouth, which is shown in figure 3. The solid feed will be pushed into pieces by spring force and fall down freely. Generally speaking, the feed will not be pushed to solid in the conveying plate as long as feed is dry enough.

3.1 Conveying plate speed

Formula 1 is used for conveying plate work speed calculation.

\[ n_1 = \frac{m}{\rho \cdot V} \quad (1) \]

In this formula, \( m \) is weight of conveying feed per minute, kg/min; \( V \) is the capacity of conveying plate, L; \( \rho \) is the density of feed, \( \rho = 0.7 \) kg/L.

According to the size of feeding machine, outlet of feed container and the situation of casting plate, we set the conveying plate diameter \( D = 260 \) mm, worm gear angle \( \psi = 32^\circ \), conveying plate container big radius \( R = 200 \) mm, small radius \( r = 100 \) mm and high \( h = 60 \) mm, as shown in figure 3.

\[ v = h \times \left( \frac{\pi R^2 - \pi r^2}{2} \right) \quad (2) \]

According to the formula 2 and parameters above, we can calculate conveying plate capacity which is 1.414 L.

We assume that the best casting feed speed is 6 kg/min, based on \( \rho \), \( V \) and the formula we can obtain conveying plate speed, \( n_1 = 6.016 \) r/min.

3.2 Rotation speed of feeding motor

The conveying ratio of conveying plate’s worm gear with worm is 1:60, so the conveying motor rotation speed can be calculated in the formula 3:

\[ n_g = 60 \times n_1 \quad (3) \]

In formula 3, \( n_g \) is conveying motor rotation speed, \( n_1 \) is conveying plate rotation speed, we plug the conveying plate rotation speed \( n_1 \) into formula 3 and can get conveying motor rotation speed which is 363.66 r/min.

4 Design of casting mechanism
4.1 Design of casting plate
To avoid a large number of feed broken by collision with casting plate, we use centrifugal acceleration feeding to replace the traditional collision feeding. The inlet of feed casting plate is designed above the center of the casting plate, because the linear velocity is small in the center of casting plate, so that the feed in the center has a small collision force with casting plate’s accelerating plate. By this way, we can reduce the breakage rate of the feed.

Some feed falling in the center of the casting plate get a zero linear velocity, which are difficult to obtain the appropriate centrifugal acceleration quickly. In order to solve the problem, a cone in the center of the casting plate is set to make the feed slide to the accelerating plate at a small linear velocity. The linear velocity of feed sliding to the accelerated plate can be changed by changing the size of the cone, and then the feed collision force can be controlled.

The ADAMS software simulation shows there is very little feed bouncing when they hit the acceleration plate. The bouncing feed fall on the surface of the floor near the cast plate. A plate cover is set on the plate, as shown in figure 4. ADAMS simulation with a plate cover shows that upward bounce feed that hit plate cover are blocked back, and then fall on the plate and cast out again.

**Figure 4.** Casting mechanism

4.2 Diameter and dip angle of casting plate
If keep the feed casting motor at a certain speed, we can increase the feed casting distance by changing the plate dip angle between 0° - 45° or increasing plate diameter. In the process of designing the feed casting plate, keep plate dip angle at 0° first and calculate a flat feed casting plate diameter, then increase the plate dip angle and decrease casting plate diameter to make sure that the max feed casting radius can reach 9 meters.

Ignoring the wind resistance, on the condition of plate dip angle which is at 0°, there is a relationship among the max feed casting radius \( S \), distance from water surface to feed casting plate \( H_1 \), feed casting plate radius \( r_3 \), time of feed casted out on the air \( t \) and feed casting out speed \( v_0 \).

\[
\begin{align*}
S &= \frac{250}{2} \pi/\omega \text{ } \text{mm} \\
H_1 &= \frac{1}{2} gt^2 \\
v_0 &= \omega r_3
\end{align*}
\]

(4)

In the formula: The max feed casting coverage radius is designed as 9 m. \( H_1 \) is 35 mm. \( \omega \) is the rotation speed of plate whose max working speed is \( \frac{250}{2} \pi/\text{s} \). \( g \) is gravity. Then plug the value of \( S, H_1, \omega \) and \( g \) into the formula (4) to calculate the \( t \) whose valve is 0.26 735 s and the feed casting plate radius \( r_3 \) is 1 28.7 mm. This result means when plate dip angle is 0° and the estimated max feed casting coverage radius can reach 9m, and the feed casting plate radius \( r_3 \) should be 1 28.7 mm.

To make the feed concentrated in the center of the casting plate after falling off, a small dip angle is designed for casting plate, and we preset the casting plate dip angle is \( \theta \). In order to determine the dip angle and radius of casting plate, a casting feed simulation experiment result by ADAMS is shown in figure 5. In this simulation, we decrease the casting plate radius and increase the casting plate dip angle to build different simulation model. The simulations result show that when the casting plate dip angle is 10° and radius is 125 mm, we can get 9 m feed coverage, then we can decide the casting plate size and shape like this.
5 Control of catamaran casting paths
In order to make the mobile platform and catamaran walk along the specified paths, the mobile platform control system is developed. Different BeiDou signal receiving systems are integrated, such as paths input system and choice system of control mode and some other hardware system. The navigation system test uses the M300 system navigation receiver as a reference benchmark receiver, and enhances the system by BeiDou foundation for difference data and get real-time cm-level positioning accuracy of RTK fixed solution, which will be used as benchmark to be compared when testing data area accurate. Test power dividers are used to obtain the satellite signals that GNSS antenna receive to offer to reference benchmark M300 receiver. Testing receiver MN110 and K500 at the same time, each receiver is used to eliminate system error caused by using different receiving antenna. After comparing the test results, receiver K500 is used to achieve Amish level precision navigation.

6 Conclusions
In the process of designing the 360° feed casting machine for shrimp feeding in this paper, the catamaran corporate with this 360° feed casting machine to make sure the feed can cover the shrimp pond uniformly. An open plate with a small dip angle used to cast the shrimp feed, which can reduce the breakage rate of the shrimp feed. The rotation speed of conveying motor can be changed to control the feed speed and the casting motor rotation speed can be changed to control feed coverage distance. This system is driven by a battery and a prototype machine was built to do the feeding tests. In the test, the catamaran cruises along preset feed casting paths to complete the feed casting, where feeding speed and the distance of casting feed can be changed according to the need. The machine meets the design requirements and lays a good foundation for further development of intelligent feeding system.

Acknowledgements
This work was financially supported by Shanghai shrimp industry technology system construction (2014) No.5, the National Natural Science Fund (51309150), Shanghai agriculture science and technology promotion project (2016-1-6-4).

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