Vibration Tribology Research of Fish Head and Fishtail Directional Equipment for Larimichthys Crocea

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Abstract. The fish head and fishtail directional sorting of larimichthys crocea is a very important pretreatment auxiliary processes in automated fish processing. The theory of fish head and fish tail directional equipment for larimichthys crocea is studied in this research. Analysed the two transient conditions in a vibration cycle, they were intermittent relative sliding condition and acceleration along the plane. Through the analysis of the movement of larimichthys crocea, effective dynamic friction coefficient is calculated. Finally, according to the principle, the fish head and fishtail directional equipment for larimichthys crocea was developed.

1. Introduction
Fish pretreatment processing including Cleaning, Arranging, "Three Removal" (removal the scales, removal the fish head, gutting), Filleting, Skinning, Splitting, Trimming and other processes, The automatic fish head and fishtail directional is an important part of the automated processing of fish effectively. In this stage, the fish body is arranged in a regular manner from a non-regular state to a certain direction in order to provide "standard" raw materials for subsequent processing. If we say the effect of "three removal" is the key factor that determines the quality of pre-processing and processing of fish, then the efficiency of arranging and sorting is the key point that determines the level of automation of pre-processing and processing of larimichthys crocea at present [1]. During the process of pre-treatment of larimichthys crocea, the method of manual sorting and arranging is widely used in many country, which not only has heavy workload, high labor intensity, low arrangement efficiency, but also has some dangers [2]. Research and development for the arrangement and finishing equipment for larimichthys crocea is to solve the basic approach to the automated processing of larimichthys crocea, Therefore, we studies the stress state and movement characteristics of larimichthys crocea in vibrating equipment, and provides a theoretical basis for the design of the head and tail directional equipment for larimichthys crocea.

2. Derivation of effective dynamic friction coefficient
Schematic diagram of vibration equipment shown in figure 1, the friction coefficient includes the static friction coefficient and the dynamic friction coefficient, static friction coefficient $f_s$ [3-5], the
ratio with the force pull the fish from the rest began to slide $S_{\text{min}}$ and positive force $N$, expressed as $f_s = S_{\text{min}} / N$, the dynamic friction coefficient $f_s^k$, the ratio with the minimum pulling force required to accelerate the movement of the fish along the direction of the force $S_{\text{kin}}$ and positive force $N$ expressed as $f_s^k = S_{\text{kin}} / N$. The direction of the vibrational force and the direction of the positive pressure are perpendicular, the simple harmonic force vibration curve as shown in figure 2. When the pulling force is large enough $S > S_{\text{min}}$, the fish began to slide on the plane. There may be two relative motion states at this time: (1) Intermittent relative sliding, (2) The acceleration of the fish body along the plane [6-7]. Starting point of vibration $t=0$, The transient state of the two relative motions in the period of the vibration as follows:

(1) Intermittent relative sliding
   ① The first stage, $t=0 \sim t_1$, at this time $S \leq S_{\text{min}}$, Fish remain stationary.
   ② The second stage, $t=t_1 \sim t_2$, at the moment $t_1$ when the force $S$ is large enough, namely $S > S_{\text{min}}$, the fish began to slide on the plane, Stopped at the moment $t_2$, this stage is the region A in the figure 2.
   ③ The third stage $t=t_2 \sim t_3$, the fish remain stationary.
   ④ The fourth stage $t=t_3 \sim t_4$, fish body sliding on the plane, stopped at the moment $t_4$, this stage is the region B in the figure 2. repeat the process in the next cycle.

(2) The acceleration of the fish body along the plane

The first kind of exercise isokinetic movement, gradually add $S$ value to $S = S_k$, made coincide $t_2$ and $t_3$ in the same point, $\omega t_2 = \omega t_3 = \omega t_1 + \pi$, from the second stage direct transition to the fourth stage, at this time, it is transferred from the intermittent motion acceleration along the sliding stage. So that there $S_k = S_{\text{kin}}^*$, based on this value, effective dynamic friction coefficient can be calculated, define the forward direction of the X axis along the S direction, forward direction of the Y axis along the $F(t)$ direction, The differential equation of the relative motion of the fish body can be written as

$$
\begin{align*}
  m\ddot{x} &= S - f_s N \frac{\dot{x}}{\sqrt{\dot{x}^2 + \dot{y}^2}}, \\
  m\ddot{y} &= F_0 \sin \omega t - f_s N \frac{\dot{x}}{\sqrt{\dot{x}^2 + \dot{y}^2}}
\end{align*}
$$

Figure 1. Schematic diagram of vibration equipment
Figure 2. Curve of force and vibration
Command $u = m \ddot{x}$, $v = m \ddot{y}$, then the above formula can be transformed into

$$
\begin{align*}
F_1(u, v) &= u + f_i N_s \frac{u}{\sqrt{u^2 + v^2}} - S = 0 \\
F_2(u, v) &= \dot{v} + f_i N_s \frac{u}{\sqrt{u^2 + v^2}} - F_0 \sin \omega t = 0
\end{align*}
$$

Utilize the Galerkin method to solve the above formula, in the time period ($t_1 \sim t_2$), approximate solution is

$$S^2 = f_i^2 N_s^2 - \frac{\alpha^2 F_0^2}{4} \left[ \int_{t_1}^{t_2} \sin \omega t \sin \omega_0 (t - t_1) dt \right]^2$$

When $t = t_1$, there is

$$F_0^2 \sin^2 \omega t_1 = f_i^2 N_s^2 - S^2$$

The relationship between $S$ and $\omega$ can be solved by the following two formula.

When $S = S_k$, $\omega = \omega_k$, the following results can be obtained

$$
\begin{align*}
S_k^2 &= f_i^2 N_s^2 - \frac{\pi^2}{16} F_0^2 \cos^2 \omega_k \\
F_0^2 \sin^2 \omega_k &= f_i^2 N_s^2 - S_k^2
\end{align*}
$$

The approximate value of $S_k$ is calculated.

$$S_k = \sqrt{\frac{f_i^2 + \alpha f_i^2}{1 + \alpha} N_s^2 - \frac{1}{1 + \alpha} F_0^2}$$

In this formula, $\alpha = \frac{16}{\pi^2} = 1.6211$

Therefore, the effective dynamic friction coefficient can be calculate as.

$$f_k^2 = \frac{S_{k_{\text{sum}}}^2}{N_s} = \frac{S_k}{N_s} = \sqrt{\frac{f_i^2 + 1.6211 f_k^2}{2.62}} - 0.38 \left( \frac{F_0}{N} \right)^2$$

3. Fish head and Fishtail Directional Equipment

The fish head and tail directional equipment of this research is an improved machine based on the Arenco machine, its work needs the cooperation of the quantitative conveyor. Quantitative conveyor according to the default processing efficiency pull a certain amount of larimichthys crocea into the feeding through, and then tilted bucket elevator will pull larimichthys crocea continuously into vibration through of the machine, the bottom of the trough affixed with a special friction material, and do not stop the reciprocating vibration, Fish fall in the trough, due to the fish scales (only inverse scale can be pull forward), when the fish fall head-to-export, it will go out directly from this slot, the rearward exit will be vibrated to the tail of the trough, past the wheel of the Ninon, go out in the paired slot.
The middle of the equipment is a long toothed belt, the size of which can only be passed through one fish, the excess fish is recovered by the recycling conveyor to the turnover box, and the rear of the equipment is a turning device, forcing the fish to the right side.

After the machine, the fish head is facing forward, the belly is in right side, a column arranged in a row, the fish will be accurately loaded into the next process of fish baskets.

There are many small scales on the body of the larimichthys crocea, the part of the body rich in muscle tissue. Fish head consists of fish bones. The tail part of the fish is flat. The differences of the fish body structure determined that the frictional characteristics of each part are different.

While the fish body continuously moves along the forward direction on the vibration through (as shown in fig. 4), the fish body contacts the side surface of the vibration through along the length direction of the fish body to generate a lateral force.

The fish body center of mass close to the head, and the friction angle gradually increased along the body length direction, the performance of friction angle appears as the smallest in fish tail and maximum in fish head.

The fish body enters the trough with head-on-front posture, the friction force along the scale is greater than the friction force inverse the scale, so that the fish can move forward and turn from the irregular arrangement to the head of the fish movement consistent state.

The fish body enters the trough with tail-on-front posture, the friction force along the scale is greater than the friction force inverse the scale, so that the fish can move backward, until after the movement to the turntable, it will turn 180° with the turntable, which turned into the head-on-front posture, then move forward from the front at the vibration through. So fish with any initial posture into the vibration through, in the exciting force and friction action, cooperated with the turntable, the fish will gradually complete head and tail directional action.

4. Conclusion

1) According to the principle of fish head and tail orientation, combined with the theory of vibration transmission, two transient states of intermittent relative sliding and acceleration along the plane of a larimichthys crocea were studied. Deduced the effective dynamic friction coefficient calculation method of larimichthys crocea, designed a fish head and tail directional equipment, fish through the equipment to achieve the purpose of alignment head and tail rapidly.

2) When the friction force of fish body is too small, it is not enough to drive the fish move forward, while the torque generated cannot make the fish steering; when the friction force of fish body is too large, the fish move forward faster, the torque applied along the length of the fish body also increases, the time it takes for the fish to finish turning in the forward direction are shortened.

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