Monitoring Different Type of Fish Around Tidal and Oceanic Current Turbines in Water Tank

Takero Yoshida [#1], Jinxin Zhou [*2], Sanggyu Park [*3], Daisuke Kitazawa [#4]

[#] *Institute of Industrial Science, The University of Tokyo,*
5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8574, Japan

[1]tyoshida@iis.u-tokyo.ac.jp

[4]dkita@iis.u-tokyo.ac.jp

[*] *Graduate School of Engineering, The University of Tokyo,*
5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8574, Japan

[2]jxzhou@iis.u-tokyo.ac.jp

[3]psg6709@iis.u-tokyo.ac.jp

***Abstract*— Tidal and oceanic currents are promising marine renewable energy. However, there is a concern about potential effects on marine environment and organisms to install such kind of device in the ocean. In particular, collision with marine species and turbines is still unknown and this collision risk is a great concern among regulators and developers. If we attempt to install the device at a site where fishery is major industry, regulators and developers need to negotiate with local fishermen in advance, moreover they need to cautious it during operation. Therefore, several experiments were conducted in terms of collision risk. Taya [1] and Zhang et al. [6] carried out for an experiment with just one type of fish. Based on their research, another type of fish is examined in this research to show different behaviour around turbines.**

***Keywords*—- Fish, Marine renewable energy, tidal and oceanic current, striking risk, water tank experiment.**

I. Introduction

Tidal and oceanic currents are expected to generate power as renewable energy. As their development progresses, their environmental impact assessment is also remarked. According to some reports [2][3], environmental impact such as underwater noise, it is said that electromagnetic field, and etc. have minor effect for a single device of power generation. If there are multiple devices as array in the future, the effect may be concerned. However, striking between turbine blade and marine animals is the problem for a single device. Tidal and oceanic current power generation use rotating blades in the ocean. It may damage marine animals once striking occurs. Especially, when the device is installed where fishery is a major industry. Fishermen concern the risk of striking with fish and turbine.

So far, Viehman & Zydlewski [4] measured fish around tidal current turbine. Also, there are several water tank tests to understand how fish behave around turbine. For example, Amaral et al. [5] conducted an experiment using a model of 1/10 scale. Taya [1] and Zhang et al. [6] proposed a similarity law to compare actual field and laboratory-scale experiment. Taya [1] and Zhang et al. [6] conducted an experiment using "Himedaka (Oryzias latipes, Japanese killifish)", and it is not wild fish. Nevertheless, striking was not reported by their researches. This research refers to the work of Taya [1], and another type of fish was investigated. The fish in this research is wild and it has a sensitive characteristic, and it may result in different result of Taya [1] and Zhang et al. [6]. From the result, fish behaviour around turbine is discussed.

II. Method

The experiment was conducted at Marine ecosystem engineering laboratory, Institute of Industrial Science, The University of Tokyo. A water tank (5 m x 1 m x 0.5 m) that equips wave and current generator was used for this experiment. A small partition (1.8 m x 0.3 m x 0.4 m) was installed in the water tank to release fish. The depth of water was set to be 0.35 m. As illustrated in Fig. 1, observing area is 0. 6 m and a model of turbine was settled within the area. The diameter of the turbine is 0.25 m. As above mentioned, the water tank has an ability to generate current, however it is weak to rotate the model of turbine. In order to achieve desired rotating speed, we used a motor and combined it to the turbine. The tip speed ratio of this turbine was designed as 5, thus the tip speed is 5 m/s if we assume water current is 1 m/s.

An underwater camera was used to monitor the behaviour of fish around the turbine. The experimental conditions were the almost same as those conducted by Taya [1]. Five fish was selected and they were released in the observation area. The experiment begun after they get accustomed to the environment. The experimental time for each case is 11 min, and then the behaviour of fish was analysed. Permission of animal experiment was obtained by the university to get prepared for the experiment.

In terms of similarity law, tip speed and maximum swim speed of fish were considered. It is because we investigate whether the fish can avoid the turbine or not when the fish approaches to the turbine. The water current speed is another important factor, nevertheless the water tank has a limitation to generate the current. Thus, it was excluded in the consideration of similarity law.

The maximum swim speed of fish relates to their length, and it can be expressed as following equation.

$$U = \frac{0.2 \cdot f \cdot l}{St} \tag{1}$$

Where U is the maximum swim speed of fish, f is the frequency of tail, l is the length of fish, St is the Strouhal number. The frequency of tail partly depends on the specie of fish, however it is generally said that the frequency is 10-20 Hz. Here we assume it as 20 Hz. The Strouhal number of 0.33 is used as representative value.

Let us assume that the length of fish is ranging from 0.1 to 1 m in the actual scale, the maximum swim speed can be estimated as approximately 1.3 - 12 m/s. Then the ratio between the maximum swim speed and tip speed is approximately 0.4 – 3.8 when the tip speed is 5 m/s. In the experiment, the rotating speeds of the turbine were set to be 0 and 20 rpm. Their tip speeds are 0 and 0.26 m/s, respectively.

The experimental fish is "Tamoroko (Gnathopogon elongatus)" as shown in Fig. 2. The length is roughly 0.04 – 0.05 m, and the maximum swim speed is 0.48 – 0.6 m. In this case, the ratio between the maximum swim speed and tip speed is approximately 0.4 – 0.5.

The fish behaviour around the turbine is classified as follows. When fish passes outside the area of rotating blade, it is passing. When fish enters inside the area of rotating blade, it is entering. When fish changes its movement at the turbine blade, it is avoiding. When fish returns in front of rotating blade, it is returning. When fish strikes the rotating blade or high risk of strike, they are classified as striking. The schematic illustrations in terms of classifying fish behaviour is shown in Fig. 3.

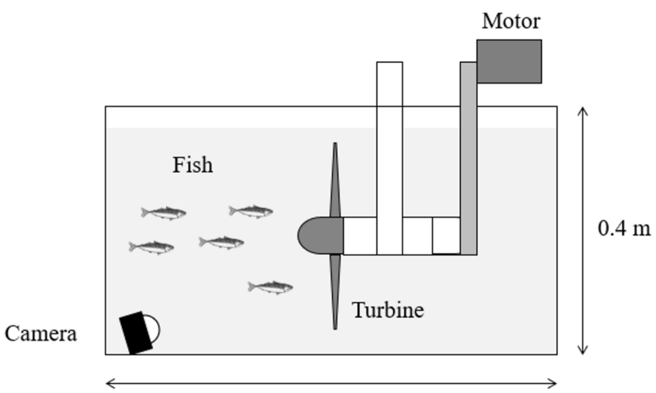

Fig. 1 Schematic illustration of experiment, underwater camera monitors fish around a model of turbine

Fig. 2 A picture of experimental fish "Tamoroko (Gnathopogon elongatus)"

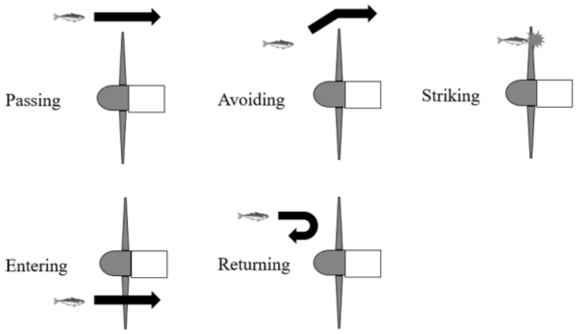

Fig. 3 Classification of fish behaviour: passing, avoiding, striking, entering, and returning

III. RESULT

Fig. 4 is a snapshot of experiment captured by the underwater camera. Fish behaviour around the turbine was classified according to Fig. 4 by analysing the movie.

Fig. 5 shows the probability of fish behaviour versus each rotating speed. There is no water current in this result. In most cases, passing outside the turbine blade is the major behaviour. Entering into the area of rotating blade becomes less with increasing rotating speed. On the other hand, returning and avoiding increase with increasing rotating speed. Striking was not shown in this result. The trend of this result is the almost similar to those conducted by Taya [1] and Zhang et al. [6].

Next, the water current was occurred using small water pump. The current speeds were roughly 0.05 and 0.08 m/s. Fig. 6 is the result with and without current. Two cases without current are shown in the figure, however they are almost similar results. The probabilities of passing, avoiding, and returning are also show similar with and without current. It is almost identical to the results of different type of fish conducted by Taya [1] and Zhang et al. [6].

Here, the remarkable trend is striking. It was not striking, however, there were quite high risks of striking. Thus the behaviours were classified as striking. Fig. 7 shows the time series of this event. No. 1 – 5 show the snapshots before and after high risk of striking. In No. 1 and 2, a fish is approaching to the blade. In No. 3 and 4, the fish is avoiding just before striking.

The experimental fish "Tamoroko" reacts the current, and if they feel the current and distract the turbine, striking may happen. “Tamoroko” is wild and very sensitive fish and they are likely to react moving objects rather than “Himedaka” which was not wild and used in the experiment by Taya [1] and Zhang et al. [6]. According to Taya [1] and Zhang et al. [6]., they couldn’t confirm striking, however the result of this paper shows there may be risk of striking for such kind of sensitive fish.

In addition to this, sensitive fish is likely to become panic, for instance when a predator is approaching to them. The fish can avoid the turbine in the normal situation, nevertheless once they are affected by external factor, current, and night, striking risk will be high.

Fig. 4 A snapshot of recorded image. Fish is passing below the turbine.

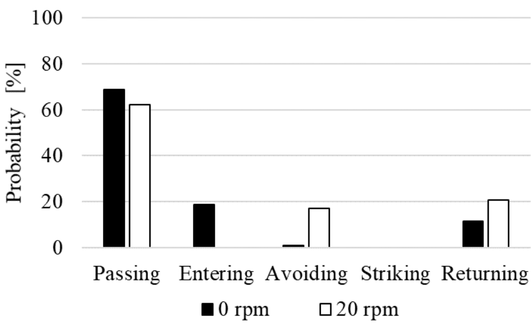

Fig. 5 Probability of fish behaviour for rotating speeds of 0, 5, and 20 rpm

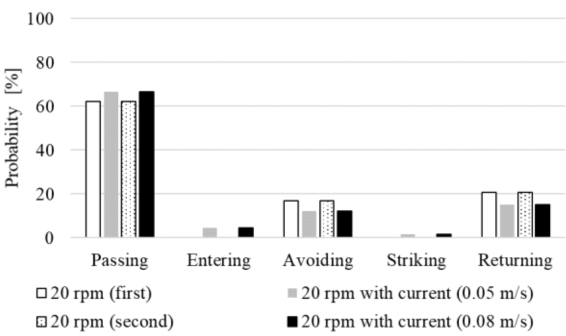

Fig. 6 Probability of fish behaviour with and without current in the case of 20 rpm

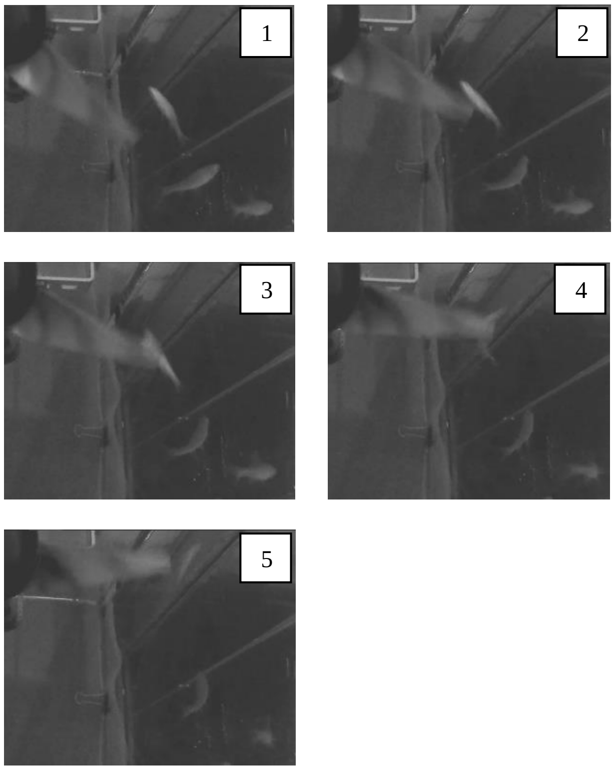

Fig. 7 Probability of fish behaviour for rotating speeds of 0, 5, and 20 rpm

IV. Conclusion

This paper showed fish behaviour around turbine by water tank test. In almost cases, fish passes outside the turbine, meanwhile there were risks of striking for sensitive fish with a quite low probability.

According to Viehman and Zydlewski [4], there were higher risks at night because of difficult detection of turbine. As a next step, the water tank test will be conducted in the night situation. Also, we need to obtain the data at the actual turbine settled in the ocean. From these researches, we can accumulate information about fish behaviour around turbine and it results in eco-friendly operation.

Acknowledgment

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