NUMERICAL AND EXPERIMENTAL STUDY OF LURE MOVING IN WATER

Wataru Sekiguchi[1], *Naoya Takahashi*[2], *Shigeho Noda*[3], *Ryutaro Himeno*[3]

(1. Graduate School of Engineering, Tokyo Denki University, Tokyo, 120-8551, Japan;
2. Department of Engineering, Tokyo Denki University, Tokyo, 120-8551, Japan;
3. Advanced Center for Computing and Communication, RIKEN, Japan)

Abstract: The motion of a lure in water is investigated experimentally and numerically. The lure motion in water of a passing water tank is observed, and the periodic motion is found. From the Fourier analysis, it is found that the frequency with the largest amplitude in the lateral direction depends on the lip width of the lure. To understand the lure dynamics, a numerical simulation of the flow field around the lure is performed. The shape is measured using an X-ray computer tomography and converted into a voxel model. From visualization, it is found that vortex sheds from its lip correspond to the vibration frequency of the lure.

Key words: fishing lure; passing water channel; voxel model; X-ray computer tomography; computational fluid dynamics(CFD)

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INTRODUCTION

A lure for fishing is one of the most popular gadgets for anglers. At fishing shops, all kinds of lures are assorted: Shape, weight, color, and size, etc. And the anglers buy and make the lures which could be "attractive" for fish. Although the lure has a simple shape, it can simulate live bait, which takes a complex motion in water.

The fluid dynamics of the motion of live fish attracts many researchers. Lighthill[1] investigated the motion of live fish based on the mathematical physics, and Azuma[2] based on the aerodynamics. Sakakibara, et al[3] investigated the motion of live fish experimentally using Stereo-PIV and showed its characteristic change of fluid field. On the contrary, only a few analyses of the motion of the lure on the viewpoint of the fluid dynamics are reported. Miki, et al[4] investigated the diving behavior of the lure experimentally, and Daida, et al[5] investigated characteristics of crank bait lure changed by the aspect ratio of the lip.

For choosing or designing lures, good anglers/designers obey their own standards of good lures, and the standards depend mainly on their experience. For novice anglers and designers, who have little experience, it is useful to refer the knowledge of the movement of the lure based on the fluid dynamics.

The purpose of this paper is to understand the movement of the lure in water experimentally and numerically. The lure we choose is the RAPALA CD-11 (Fig. 1), which is one of the most popular and typical lure in the world. It is important for us to unify its shape, color and material, etc. The key component of this lure is a "lip": A slip fixed to the front lower part of the lure. Although the hook is the most important component of the lure, we remove it due to the safety reason.

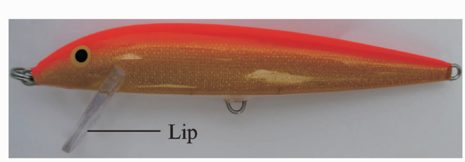

Fig. 1 Fishing lure RAPALA CD-11

The movement of the lure may be strongly

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Corresponding author: Naoya Takahashi, Associate Professor, Doctor of Science, E-mail: n.takahashi@mail.dendai.ac.jp.

affected by the change of its Reynolds number Re, defined as $Re=Ud/\nu$. Here, d is the length of the lure (11.2 cm), U its velocity relative to the water, and ν the kinematic viscosity of water (about 1.00×10^{-6} m^2/s at 20 °C). As a preliminary test, the movement of lures in water is investigated by using a passing water tank (PWT), shown in Fig. 2. In the test section of PWT, the lure moves periodically with various frequencies, particularly in the lateral direction.

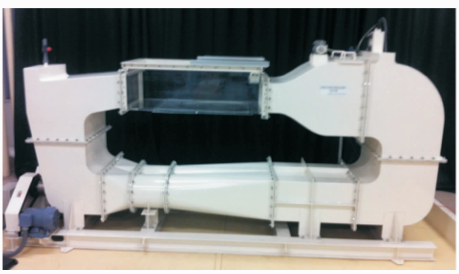

Fig. 2 Passing water tank system (West Japan Fluid Engineering Laboratory V2-1A)

To understand its periodic motion, the flow field around the lure is numerically investigated. Its shape is measured by using an X-ray computer tomography and converted into a voxel model directly. The voxel model is fixed in the center of the flow field, and numerical simulations are performed. From the visualization results, we found the emergence of the trailing vortex pair on the edge of the both sides of the lip, which affects the periodic motion.

1 EXPERIMENTAL SETUPS AND RESULTS

The preliminary experiments are performed in PWT. The lure is tied a knot at its head, and sinks in water of the PWT test section. A high-speed camera (CASIO EX-F1) is set under the floor of the test section, and the lure movement is recorded with 300/600 frame/s. The lure position is extracted from the movies using motion analysis software.

Fig. 3 shows the time evolution of the positions of the head, center and tail of the lure. They move periodically with various frequencies,

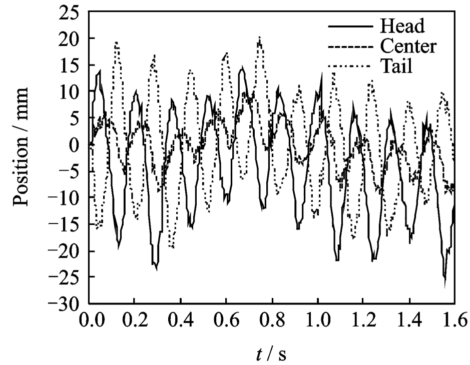

Fig. 3 Time evolution of positions of lure

and particularly in the lateral direction. Based on the frequency of the lateral vibration f and the width of the lip l, the estimated Strouhal number, $St=fl/U$, is 0.13.

2 NUMERICAL SETUPS AND RESULTS

The shape of the lure is measured using an X-ray computer tomography, and converted into a numerical voxel model directly. To improve the shape approximation in the voxel, both VOF/AOF methods are applied[6].

The numerical simulation of the flow fields around the voxel-modeled lure is performed by using the solver of "V-FLOW VOF3D" by RIKEN[7]. It solves the unsteady Navier-Stokes equation numerically with the QUICK scheme to the convection term, the Adams-Bashforth method to the time integration, and the HSMAC method to the entire system.

Fig. 4 shows a numerical result of the flow field at $Re=1\ 000$ around the lure. The streamlines are used to visualize the velocity vector

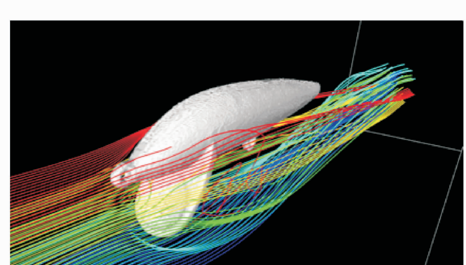

Fig. 4 Visualization result of flow field around lure using streamlines

field. The streamlines on the upper side of the lure flow along the surface, and keep their direction to the downstream. On the other hand, the streamlines under the lure change their direction. The streamlines from the front of the lip change their direction to approach the tail of the lure gradually, and particularly twine behind the lip. This streamline deformation suggests the emergence of the vortex due to the lip.

Fig. 5 shows the velocity vectors of the simulated flow field on the section of the center observed from the downstream. The central small black area without any velocity vector corresponds to the lure. Under the area, the velocity vectors rotate in the lower right and left, and their direction of rotation is different each other. The similar structures are also observed behind the lip. The vortices generate on the lip edge and trail in the downstream direction.

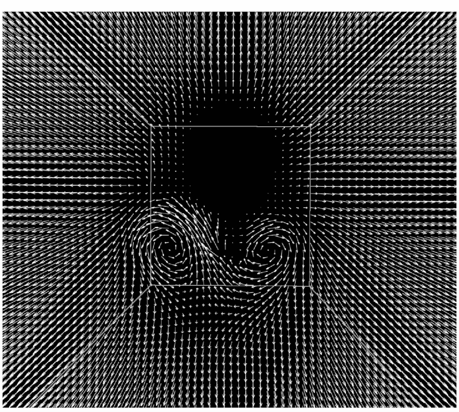

Fig. 5 Visualization result of flow field using velocity vectors

It is supposed that the periodic motion of the lure can be described by the asymmetry of the trailing vortex and the line tension. The two vortices with opposite rotation have slightly different amplitudes in the PWT experiment. The difference will move the lure in the lateral direction. Simultaneously, the tension of the line will also affect the lure. These two kinds of force will change the normal of the lip, and cause cutting the trailing vortex. We suppose that the mechanism can move the lure periodically.

3 CONCLUSION

The motion of a lure in water is investigated. As a preliminary experiment, the periodic motion is found. To understand the periodic motion, numerical simulations of the flow field around the lure are preformed. The shape is measured using an X-ray computer tomography and converted into a voxel model. From visualization, we find vortex sheds from its lip correspond to the vibration frequency of the lure, and suppose the emergence of the vortices can describe the periodic motion.

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References:

[1] sir Lighthill J. Mathematical biofluiddynamics[M]. Philadelphia: Society for Industrial and Applied Mathematics, 1975.

[2] Azuma A. The biokinetics of flying and swimming [M]. 2nd ed. USA:AIAA, 2006.

[3] Sakakibara J, Nakagawa M, Yoshida M. Stereo-PIV study of flow around a maneuvering fish[J]. Experiments in Fluids, 2004,36:282-293.

[4] Miki T, Daida N, Inada H, et al. Diving behaviour of lipped hard-lure changed by the body shape in the retrieving process [J]. Nippon Suisan Gakkaishi, 2001,67(1):49-57. (in Japanese)

[5] Daida N, Inada H, Hu F, et al. Hydrodynamic characteristics of crank bait lure changed by the aspect ratio of the lip[J]. Nippon Suisan Gakkaishi, 2001,68 (6):843-851. (in Japanese)

[6] Noda S, Fukasaku K, Himeno R. Blood flow simulator using medical images without mesh generation [C] // IFMBE Proceedings, World Congress on Medical Physics and Biomedical Engineering. USA: Springer, 2006: 37-40.

[7] RIKEN. The VCAD system research program[EB/OL]. http://vcad-hpsv.riken.jp/en/.

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