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Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

Measurement of swimming ability of moon jellyfish using a Particle Imaging Velocimetry

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1. Introduction

At present, studies are actively carried out on prevention of the damage caused by jellyfish in a large scale all of the world. The frequency of occurrence is increasing recently due to the complex reasons such as increase in the water temperature resulting from global warming, depletion of fish resources resulting from thoughtless overfishing, and marine pollution. The industrial damage such as reduction in the capacities of power plants located in littoral areas and plant shotdown caused by appearance of jellyfishes in quantity is on an increasing trend. Though the damage is reduced by the simple shields installed to remove them, no fundamental solution has been found due to technical problems. It is because of lack of accurate information about the swimming behavior of jellyfish.

Swimming of jellyfish can be divided into the movement by external tidal current and the swimming for which the muscles are used. In this study, we carried out an experimental research on the autonomous swimming comprised of contracting, relaxing and resting processes of the bell of jellyfish among its swimming behaviors. The representative thrust forms of jellyfish include jet propulsion and paddling like those of cuttlefish. The propulsion mechanism of jellyfish varies depending on the size, shape and type of jellyfish. It is known that jet propulsion mechanism is superior in the case of prolate-shaped jellyfishes of which the bell shape is relatively long, and paddling mechanism is formed in the case of most jelly fishes that are relatively flat and oblate-shaped[1-2].

In this study, we carried out an experimental research on the voltex structure formed in the swimming wakefield of a moon jellyfish with an oblate shape having the height to diameter ratio of 0.5.

2. Materials and Methods

Moon jellyfish (*Aurelia aurita*) is a species that appears from April and is most frequently found until November to December in Korean coasts. Moon jellyfishes 10 to 19cm in diameter and 59.7 to 290.56g in weight were collected from a shore near Yeosu in June and used for the experiment. A single camera with the resolution of '1920 x 1080' pixel and the image capture interval of 15 fps was used, and two high speed Nd-Yag laser (2W-532nm) beam generators were used to provide a light source to both sides of the object of observation using the beam width of 2mm to prevent occurrence of any occlusion. As to the tracer particle, Silver Coated Hollow Glass (SH400S33 Mean size 14 microns) was used. As to the measurement software, Thinkers EYES (PIV software) that uses the Cross Correlation PIV technique was used for image processing and acquisition of speed measurement data. An acrylic water tank of size 1200 x 580 x 430 (mm) was used as the experiment water tank as shown in Figure 1. The visualization area is 300 x 150 (mm).

The Visual Counting (VC) in all observations was carried out during daytime every 1 hour, which is about 10 nautical mile intervals. Jellyfish counting was done for a predetermined width of surface water, which is in general 5 to 10 m width, and knowing the speed of vessel, jellyfish abundance was evaluated. The speed of vessel was adjusted according to the abundance of *N. Nomurai* jellyfish for each stations (**Fig. 1**).

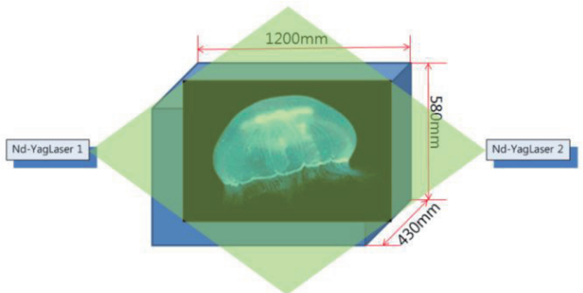

Fig. 1. Experimental Diagram of PIV Measurements for Jellyfish Swimming.

PIV (Particle Image Velocimetry) technique[3-4] is the method of analyzing the flow field by analyzing the behavior of the particles using visualization technology after inputting the particles having the same specific gravity as that of the medium of the flow field. It has a strong point that it is advantageous to analysis of abnormal flow field as multiple points can be measured concurrently.

The Cross Correlation Method[5] using grey-level means the principle of the method that determines the location of the maximum correlation coefficient as the terminal point coordinate of the velocity vector using the cross correlation coefficient as shown in the equation for the grey-levels of the

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images of two successive frames with minute interval between particles differently from the PTV (Particle Image Velocimetry) which uses the centroid positions of individual particles.

3. Result and Discussion

Figure 2 shows the result of quantitatively measuring the change in the vortex structure around the jellyfish and the bell of the jellyfish resulting from contraction and relaxation of the jellyfish using the flow visualization method. This shows some similarity to the result of Dabiri[5]. The vortex structure formed around the bell of the swimming jellyfish creates the propulsion for movement of the jellyfish. Also, in the result of a 3D simulation flow analysis for jellyfish, Park[6] has said that the vortex structure formed at the edges of the bell of the swimming jellyfish when it ascends vertically plays the role of inducing the flow around the jellyfish in the direction of the central axis of the jellyfish, and the vortex gathers around the center to create propulsion. Also this study has shown that, differently from the existing studies, the jellyfish moves to the left from the central axis, the right side of the vortical structure of the bell has faster speed, and the propulsion is obtained from the movement of the central axis resulting from the difference between the speeds of the left and right sides of the bell (**Fig. 2**).

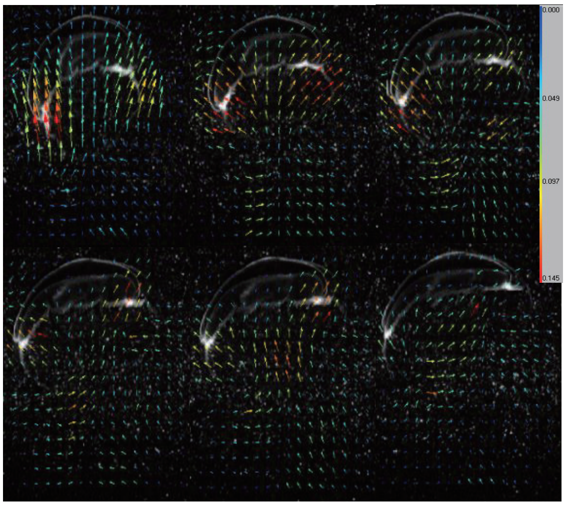

Fig. 2. PIV Vortical Structure resulting from Swimming of Jellyfish.

In an oblate structure, vortical structure is generated more actively around the bell than the central axis rather than the jet propulsion form of prolate structure.

The change in the speed at the central axis of the jellyfish of which the aspect ratio varies between 0.6 and 0.3. It can be seen that, the lower the aspect ratio is around 0.5, the more the speed decreases. The propulsion is weakened as the relaxation of the muscles of the jellyfish progresses **(Fig. 3)**.

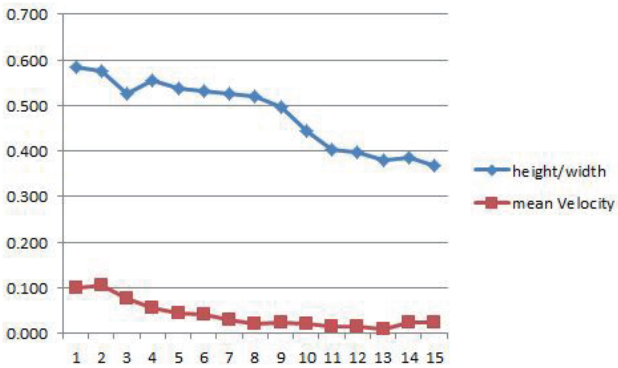

Fig. 3. Change in the Velocity Field around the Bell caused by the Change in the Aspect Ratio resulting from Contraction of the Jellyfish.

We can see the characteristics of the propulsion form of the rotational displacement of an oblate-shaped jellyfish from the similarities of the simulation result and the experiment result of the structure of the existing jellyfish bell and from the relation between the vortical structure of the left and right sides of the bell resulting from rotational displacement and the change in the velocity.

Acknowledgment

This study was supports by a grant provided by Chonnam National University.

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