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Flow Analysis of Underwater Water Jet System Using Computational Fluid Dynamics and Particle Image Velocimetry

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Abstract

The width and depth of excavation are important for the development of a water jet system for underwater surface excavation in the water. This is determined by the pressure distribution affecting the ground. Therefore, it is necessary to analyze the flow of the water jet, but it is difficult to grasp visually, and generally used sensors are difficult to use in water. To overcome this problem, the flow analysis was simulated by using Computational Fluid Dynamics (CFD), Particle Image Velocimetry (PIV) experiment was performed to confirm the accuracy of CFD and to visualize the nozzle flow. The CFD was simulated by using MIDAS NFX and various pressures of nozzle injection, velocity distribution and pressure distribution were analyzed. For the PIV experiment, the water jet system is installed at L22m x W3.5m x D3m water tank, and a 5W Nd-yag laser was installed at the surface of the water, and a high-speed camera was installed to capture the flow in the side observation field. And particles of 20 micrometer size were mixed in the water. In the results of the CFD simulations, the nozzle injection pressure, which is the measurable velocity of the PIV system was selected, the nozzle flow was visualized and the velocity distribution was measured by using the PIV experiment. The velocity distribution measured by PIV is compared with the CFD - analyzed the velocity distribution under the same conditions.

Keywords: computational fluid dynamics (CFD), particle image velocimetry (PIV), water jet

1. Introduction

The ocean takes up two-thirds of the Earth's surface, marine technology development is essential and being developed. As a result of many developments such as offshore plant and ocean exploration and offshore wind power, one of the necessary technologies is the technology of digging the sea-bed. It uses mechanical plows, drilling and cutter methods, and waterjet methods to dig the seafloor.

The method of digging the sea-bed by direct force such as plowing, drilling, and cutter method is complicated in structure, and power and operation vessel problem as water depth becomes deeper, a waterjet-based excavation method is started to be used due to waterproofing problem.

The excavation method using waterjet has a disadvantage of relatively simple structure compared to other mechanical excavation methods, but it is difficult to predict the desired excavation area. In this paper, we try to grasp the excavation area and the depth of the nozzle arrangement by assuming that the excavation method using waterjet has a great influence on the desired excavation area.

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This paper is expected to have a great influence on the nozzle placement on the desired excavation area in the water jet excavation method. In the underwater environment, we cannot use the sensors that are commonly used, and because it is difficult to quantitatively measure through experiments, we go through a lot of Computational Fluid Dynamics (CFD). In this paper, we investigate the reliability of CFD by comparing Particle Image Velocimetry (PIV) experiment with the CFD results before the CFD analysis by the nozzle.

2. Experimental Conditions

To verify the validity of the CFD before simulating the nozzle arrangement using CFD, the nozzle injection speed and flow field are measured using the PIV system.

2.1. PIV (Particle image velocimetry)

The nozzle spraying system and the laser system were installed in a water tank of length 22 m width 3.5 m depth 3 m. The nozzle injection system consists of a pump (maximum output pressure 13 bar), a solenoid valve, a pressure sensor, a flow sensor, and a nozzle. The laser system consists of a Nd-yag 3W, a laser with a wavelength of 532 nm and a width of 2 mm or less, and a wave plate to allow the laser to penetrate below the water surface. A high-speed camera capable of shooting at up to 2000 fps was installed for measurement on the side.

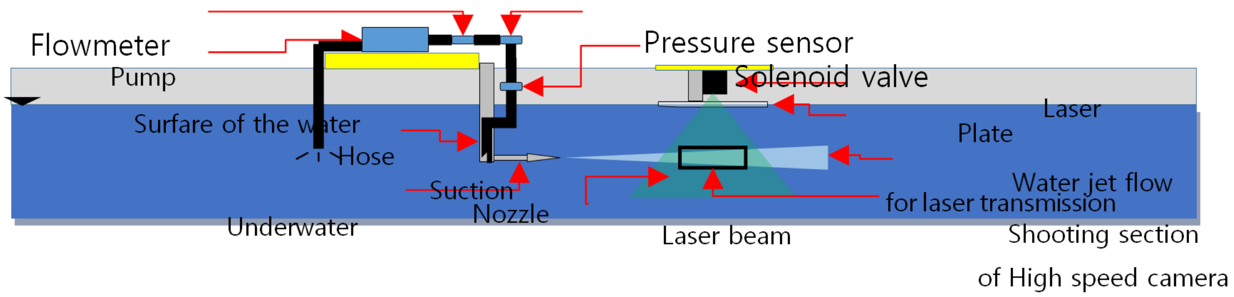


Fig. 1 PIV System

Particles of 20μm or less were dissolved in the water tank, and the pump sucks the water and discharges it to the nozzle.

PIV experiments were conducted while finding the nozzle injection pressure at which the particles were measured while changing the nozzle injection pressure.

The order of the PIV experiment is as follows:

(1) Position the laser at the desired position and align the laser sheet with the center of the nozzle.

(2) Set the high speed camera shooting position to the position where you want to measure.

(3) Control the pump rpm to discharge the desired pressure.

(4) Open the solenoid valve when the desired pressure is reached and the PIV shooting is ready.

(5) Take a picture with a high-speed camera.

(6) Make sure that sufficient amount of particles are taken clearly in the picture.

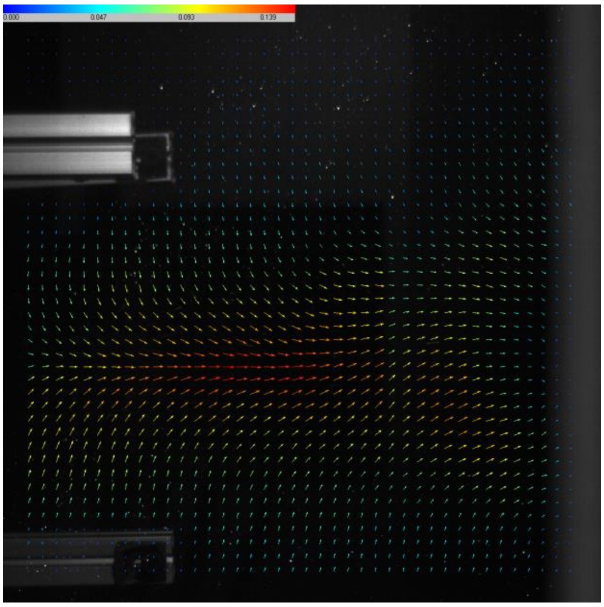
(7) After shooting is completed, process the PIV after the shot.

(a) Nozzle injection

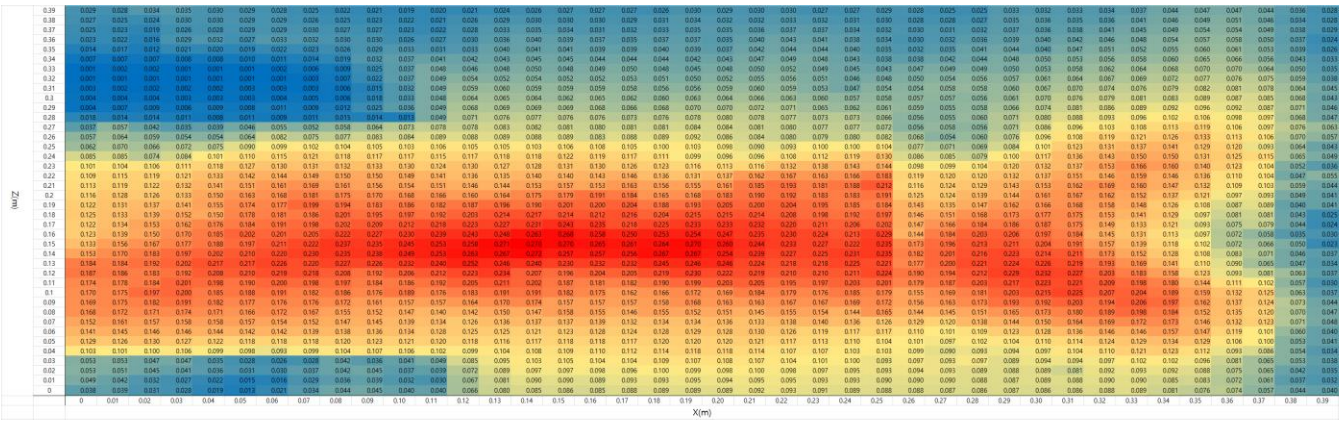
(b) PIV flow visualization

Fig. 2 Nozzle injection experiment

Experimental results show that the particle velocity is measured at 0.1 bar and the measurement speed of the high speed camera is 100 fps. The results obtained by PIV analysis are shown in the figure.



(a) Water Jet Streamline of PIV result



(b) Water Jet Flow Velocity of PIV result

Fig. 3 PIV result

2.2. *Computational fluid dynamics* (*CFD*)

To compare the CFD results with the PIV results, the experiment conditions that were tested in PIV were applied to the CFD. The CFD used NFX 2015 from Madis. Based on the design data of the nozzle shape, we made 3D shape as shown in the figure and made 229,000 elements in 1mx 1mx1m space. The pressure at the nozzle inlet end was set to 0.1 bar.

Fig. 4 Nozzle 3D shape

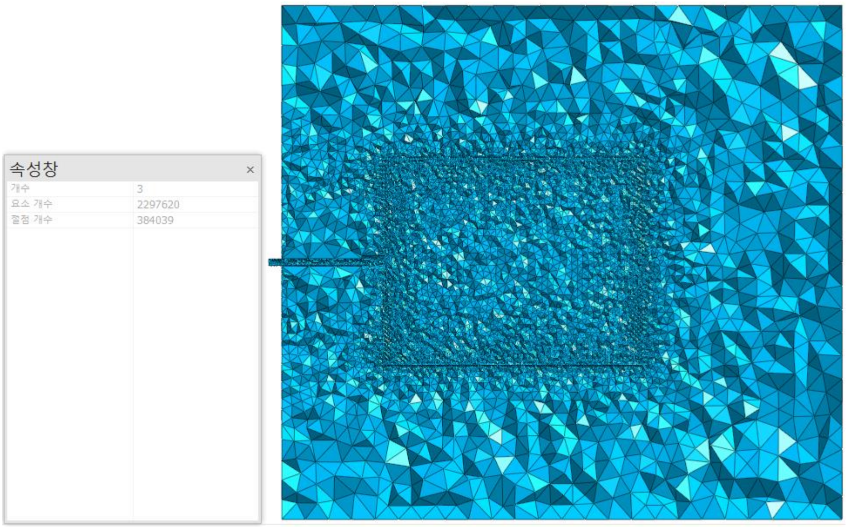


Fig. 5 Mesh generation result

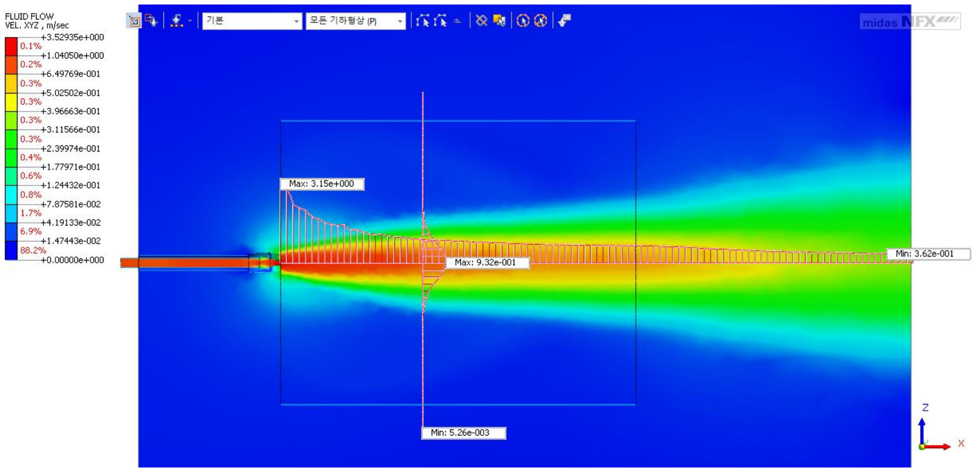


Fig. 6 Water Jet Flow Velocity of CFD analysis result

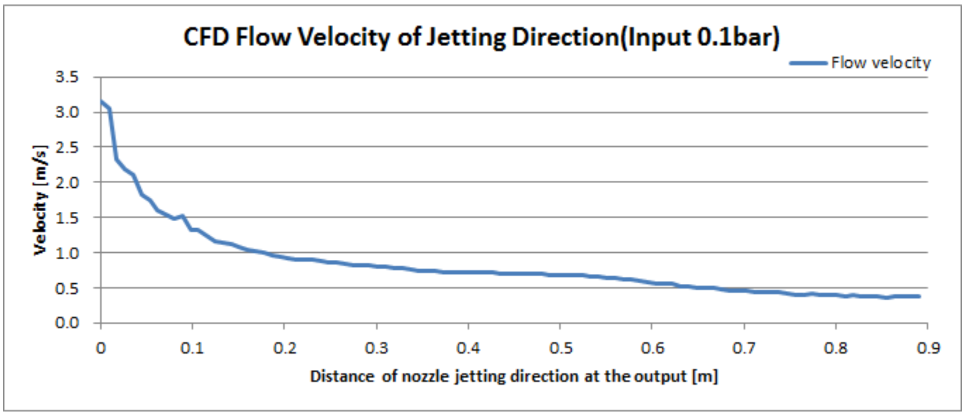


Fig. 7 Water Jet Flow Velocity of CFD analysis result

2.3. Comparison of CFD and PIV results

In order to compare CFD and PIV analysis results, the flow velocity was compared with the height of the nozzle injection center at a distance of 20 cm from the nozzle outlet end.

The PIV measurement results and the CFD analysis results were similar to each other, with the nozzle injection center velocity being the fastest, and the velocity being sharply decreasing with increasing distance from the center.

However, the difference between the two maximum flow velocity is large. The maximum flow velocity the PIV measurement is 0.27m/s and the maximum flow velocity the CFD analysis result is 0.93m/s. And velocity difference was large at 0.05m radius from the nozzle injection center.

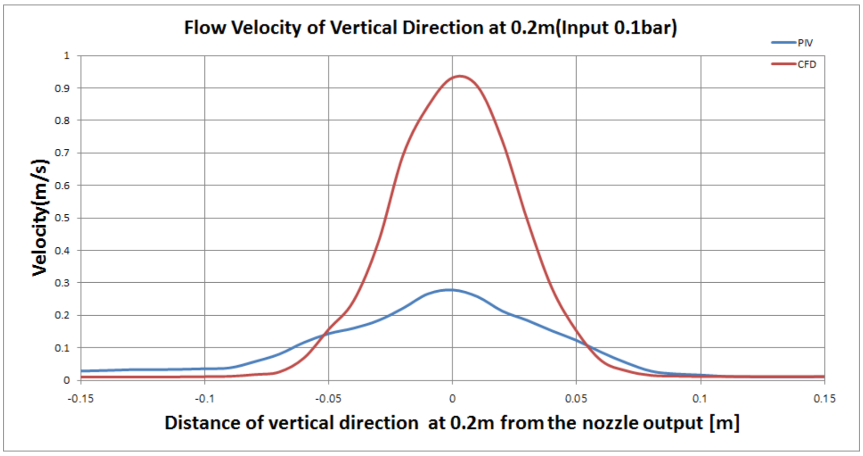


Fig. 8 Water jet flow velocity of PIV and CFD result at 0.2m

3. Conclusions

In this paper, PIV measurement results and CFD analysis results were compared in order to analyze the flow of underwater waterjet. It was thought that the validity of the CFD could be verified through the PIV, but the results of two experiments showed a great difference.

The maximum velocity of the CFD analysis result is much higher than that of PIV. This is due to hardware limitations of the PIV measurement system. The measurement speed of the high speed camera changes according to the brightness of the laser light and the actual 30cm size is measured at 100fps with 1024 x 1024 image. Then the actual measurable speed is 0.3m / s or less.

It is expected that additional PIV experiments should be conducted by changing the laser or high-speed camera. Thus, when the verification of CFD is completed first, the effect of waterjet excavation according to nozzle spacing and arrangement with CFD will be further studied.

References

[1] H. A. Kim, K. M. Kwon, H. I. Park, W. D. Jung, and H. W. Kwak, “A basic study on nozzle design of the sub-sea trenching machine,” The Korean Society for Marine Environment & Energy, pp. 387-392, November 2006.
[2] H. S. Choi, H. J. Kim, C. K. Yang, and K. Y. Hong, “A study on the excavation mechanism of sea bottom by water jetting,” The Korean Society for Marine Environment & Energy, pp. 31-36, May 2000.