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◉ 論 文

자유 표면 인식을 위한 실험 기법 개발

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Experimental Technique applied to Free surface Identification

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Key Words : Laser Doppler Velocimetry(레이저 속도계), Wave probe(파고계), Image processing(영상처리), Binarization(이진화)

초 록

본 연구는 자유표면 인식을 위한 실험 기법 개발에 관한 연구이다. 2차원 수중익에 의해 발생되는 자유표면파를 연구대상으로 삼았다. 실험은 회류수조에서 행하였다. NACA 0012 수중익을 여러가지 길이와 2가지의 앙각에 대해서 실험한 결과 생기는 비선형 자유표면파를 인식할 수 있도록 영상처리 기술을 도입하였다. 실험결과 얻은 자유표면 형상을 다른 연구자의 결과와 비교하였다. 비교결과 영상처리 기법이 자유표면을 인식하는데 대단히 유용한 도구임을 알 수 있었다.

1. Introduction

Free surface identification is very important techniques in many branches of engineering. Recently increased interests were focused on nonlinear waves. The nonlinear waves are considered to be very critical to figure out the exact mechanism of ringing, wave breaking, etc. Researches on high speed craft deal with hydrofoils. Many numerical codes are developed for the design purposes of high speed craft. There are great demands on the exact experimental results to confirm these numerical calculations. Wave probes were conventionally used to measure the wave fields. But by using wave probe only limited number of points can be measured. The wave probes themselves may disturb the flow field. Recently thanks to the development of electronic technique, image processing techniques are in use

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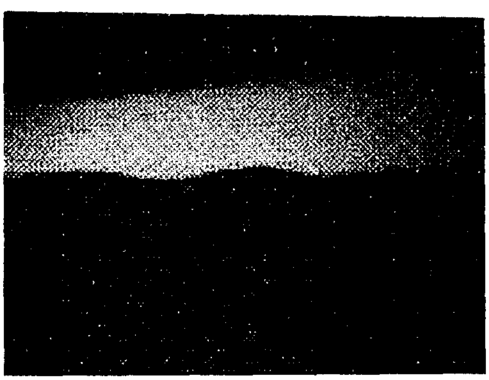
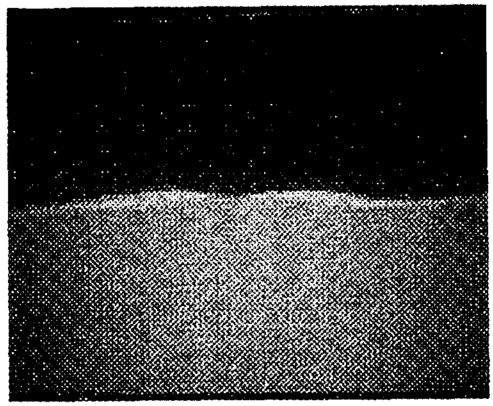
(Lindly, 1991), (Gonzalez, 1992), (Kwon, 1996). In this study, the image processing technique is adopted to figure out the wave height distribution generated by a NACA 0012 hydrofoil.

Three materials are tested to see which one is efficient. Dry ice mist was evaporated in the air. Shown in Fig. 1 (a) is the test result with Dry ice mist. The result was very sensitive to the amount of dry ice mist. The second material tested was Titanium Oxide which was mixed with water. Fig. 1 (b) shows the result. It turned out that it was very effective one. But when it comes to the experiments in large circulating water channel (CWC), it is not appropriate one. Polyvinyl chloride powder was tested to identify the free surface. Fig. 1 (c) represents the result with polyvinyl chloride powder. It was very handy and effective.

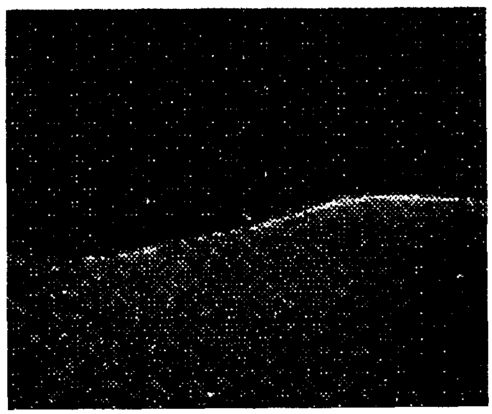
Thus, the polyvinyl chloride powders were used to identify the free surface. These powders scatter laser beams. The resulting free surfaces were recorded by video camera. The analog recordings were digitized by a DT-2853 board. Noise reduction and free surface identification were done on these digitized files. The results were compare with those of Duncan(1983). The results demonstrated that the image processing technique can be an efficient tool in free surface identification.



(a)



(b)



(c)

Fig. 1 Tested results with three material

2. Experimental setups

Fig. 2 shows the experimental setup. Laser Doppler Velocimetry(LDV) generates the ray. The ray is reflected by a mirror. The lens creates the laser beam sheet. The NACA 0012 hydrofoil is submerged in the circulating water channel. The velocity of the uniform flow was set up at 0.8 m/s. The length and width of the measuring section of the CWC were 5 m and 1.8 m, respectively. The

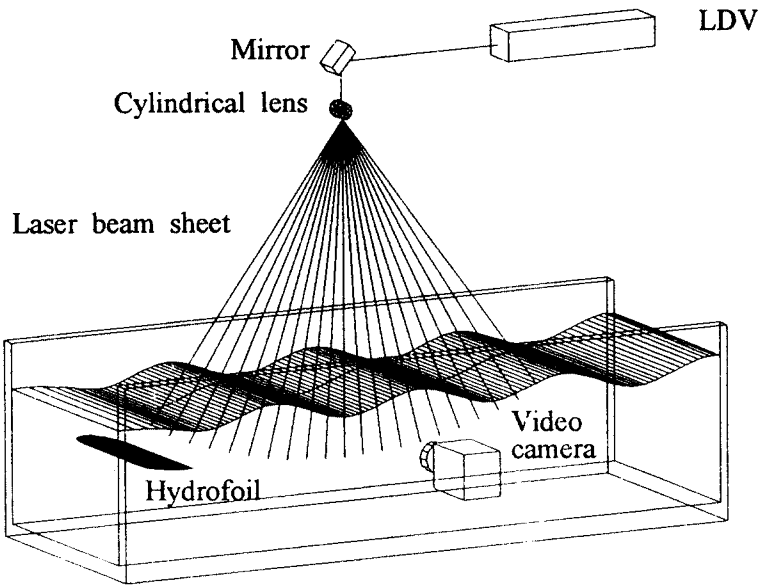


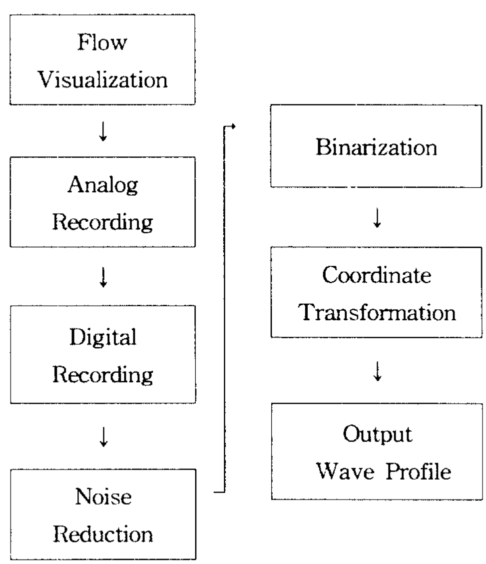
Fig. 2 Experimental set up

polyvinyl chloride powder were supplied on the free surface at the upstream of the hydrofoil. The disturbed free surface distribution was recorded by a video-camera. Since this experiment measures long range of free surface, the resulting free surface ranges were divided into three zones. The video camera records each division at a time. In other words, one flow field can be analyzed after combining these three scenes.

3. Image processing

The image processing can be readily explained by a flow chart shown in table 1. After recording the free surface, the images were acquired by DT-2853 board. The input data were binarized to reduce the noise and to identify the free surface. Since it is convenient to locate the video camera above the free surface, the results from video camera have to be transformed to get real scales. The transformation was done by the adopting equation (1).

Table 1 Image processing flow chart



Where X, Y are coordinates in the camera view plan, x, y represents real coordinates, α represents the inclined angle of real coordinates. The x coordinate indicates the direction of uniform flow. The y coordinates are perpendicular to the x coordinates in the vertical plan.

$$y = \frac{Y\lambda}{Y\sin\alpha - b\cos\alpha}$$

$$x = \frac{(y\sin\alpha - \lambda)X}{b} \tag{1}$$

The λ represents the distance between lens center to the intersection point of free surface and laser beam sheet. The b represents the distance between lens center to the camera view plan. The coordinate system of the image transformation is shown in Fig. 3.

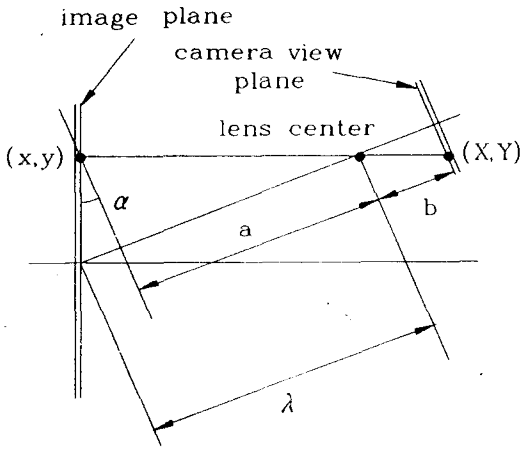


Fig. 3 Coordinate system of image transformation

4. Experiments

Experiments were done on five depths of submergence of NACA 0012 hydrofoil. The dimensions of the 2-D hydrofoil are exactly the same as was manufactured by Duncan. 5° and 10°angles of attack were tried. Table 2 shows the details of test cases of the experiments. These combinations yield 10 test cases.

Table 2 Test cases

	depth of submergence	angle of attack
case 1-1	26.1 cm	5°
case 1-2		10°
case 2-1	23.6 cm	5°
case 2-2		10°
case 3-1	21.0 cm	5°
case 3-2		10°
case 4-1	18.5 cm	5°
case 4-2		10°
case 5-1	15.9 cm	5°
case 5-2		10°

5. Results and discussions

Fig. 4 shows the original image on left hand side and the output graphic on the right hand side. The improvements accomplished on the images can be vividly shown.

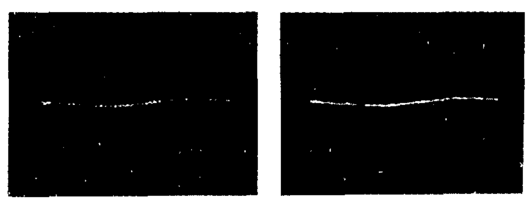


Fig. 4 Original image and binarized image

Due to the unsteadiness of the generated free surface, four results are averaged to represent the resulting free surface distribution. To show the unsteadiness of the wave profiles, two instantaneous wave profiles are shown in Fig. 5. These represent the first wave profiles recorded at 0.2 second time interval. The first wave profiles are illustrated to show the unsteadiness because the first wave profile experiences the most severe unsteadiness.

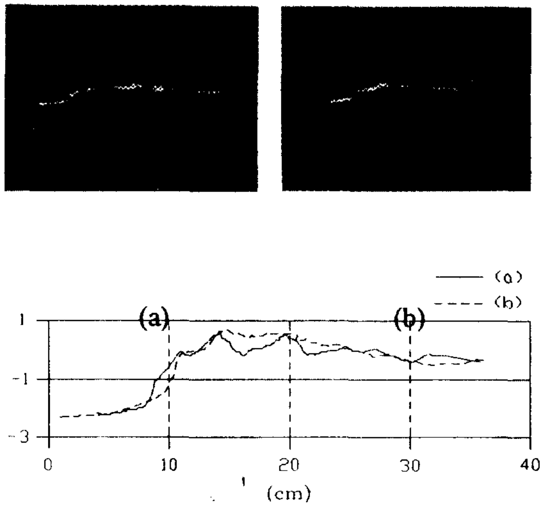


Fig. 5 Original images and wave distributions of unsteady wave [(a) $t = t_1$ (b) $t = t_1 + 0.2$ (sec)]

Fig. 6 shows the results of test cases 5° angle of attack. The results are compared with those of done by Duncan (Duncan, 1983). The experimental results done by Duncan are plotted in dashed line for the comparison purposes. The experimental results performed in this study are plotted in solid line. The present authors' results show relatively low wave heights. But the phases are in good agreement with those of Duncan. The center of hydrofoil camber line was located 27.5 cm away from the vertical coordinates of the figures. Since no experimental data are available for the 10° angle of attack case, the whole results are plotted in Fig. 7. As the depth of submergence of hydrofoil increases, the first height of trough of the wave profile decreases. As the depth increases, the wave height increases. But when the wave breaking occurs, the wave height decreases dramatically even though the depth increases. When it comes to the angle of attack, the wave height increases as the angle of attack increases.

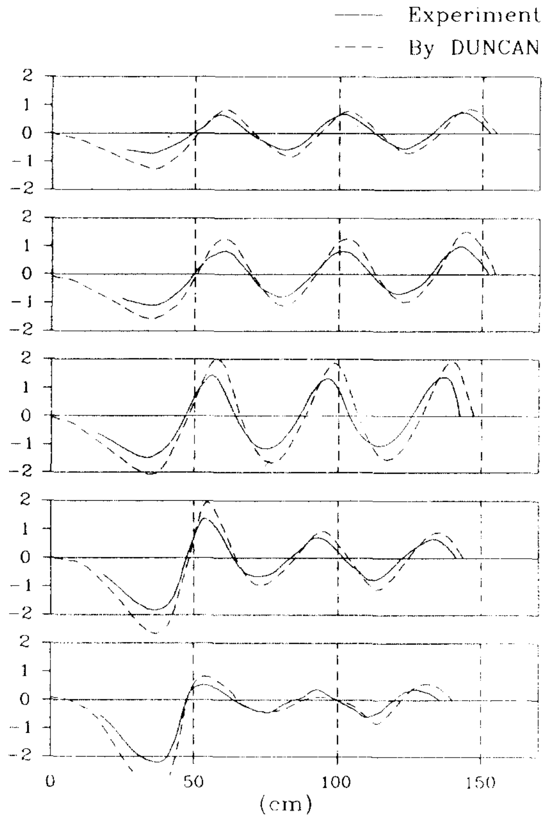


Fig. 6 Wave distribution [5° angle of attack]

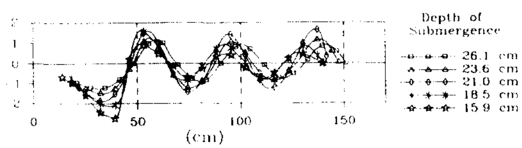


Fig. 7 Wave height distribution [10° angle of attack]

6. Conclusions

Following conclusions are drawn from the present study.

1. The polyvinyl chloride powder is an excellent material to make distinction between air and water in the presence of laser beam sheet.

2. Image processing can be a very efficient tool in free surface identification.

Acknowledgement

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