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RESEARCH PAPER

Directional attraction of fluid surface wave caused by vertically oscillating prisms

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Abstract: Experiments show that the surface wave, which is caused by a triangular prism performing simple harmonic vibration with low frequency and small amplitude on fluid surface, has directional force on float. A series of experiments and an in-depth study about this phenomenon were carried out, and the characteristics of fluid surface wave from different structures oscillation were analyzed. Experiments were launched with different vertical oscillating structures, such as triangular prism, quadrangular prism, hexagonal prism and the cylinder. The results show that the surface wave, on the direction directly opposite to the prism edge, can attract the floats, while the wave on the direction directly opposite to the prism facet has repelling interection. The relationship between the strength of attraction and sharpness of the angle is non-linear. The sharper the angle, the stronger the attraction force. When the prism becomes a cylinder which means without angle, the attraction will disappear. The experiment found and verified the fluid surface wave caused by specific structure oscillating prisms has directional attraction interection. The results are helpful for cleaning up pollutants and collecting spill oil on the water.

Key words: ocean engineering; vibration source stricture; surface wave; directed attraction; wave dynamics

Introduction

The 21st century is an era when the marine economy develops at full swing. A better understanding of ocean and the interaction between the wave propagation characteristics and its contact substances are very important for ocean engineering (including offshore oil and gas projects), marine disaster prevention, ocean shipping etc.[1–5]. In a wave property test experiment at the laboratory, the authors found that waves generated by different oscillating sources have anisotropy. Particularly, the prism edges can pull the floater towards the oscillating source while the triangular prism performs simple harmonic vibration of low frequency and small amplitude over the fluid surface. This “anomaly” has drawn great attention from the authors, usually, oscillating source can generate waves and propagate energy outward, in other words, floaters would move outwardly with the waves. Coincidentally, a physicist of Australian National University achieved the traction to an object from distance to the vertically moving plunger by three-dimensional waves produced by a special wave maker in 2014[6], but couldn’t give a reasonable explanation to the phenomenon with the current related theories. Are these “anomalies” accidental or inevitable? If inevitable, what is the functional mechanism of the directional attraction which was not known before. Whether an explanation can be given with classical hydrodynamics, modern theory of stochastic wave, and fluid-solid coupling method? What could the directional attraction of wave do in the engineering technology field? All these issues need to be answered. Review of literatures shows more studies at present are about the influence of fluid on the structure, while how vibration source structure affect water wave feature is a new research direction[7–11]. In this study, pertinent experiment was designed to study the "abnormal" phenomenon further, and analyze the effect generated by vibration sources of different structures to the fluctuation characteristics of the fluid surface.

1. Experiment design

To find out the characteristics of fluid surface wave caused by vibration sources of different structures, a set of stable vibration generation and control device has been developed, including stepping motor drive system, vertical vibration mechanical transmission, vibration sources of different columnar structures, and wave record measuring device.

The stepping motor drive system can precisely control the stepper motor rotation speed and acceleration by controlling

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the pulse frequency, realizing accurate regulation of vibration source frequency. The system consists of stepper motor and its driver and controller, specifically, the stepper motor is high torque mixed two phase stepping motor, the controller is TC55 motion controller, and the driver is JX - 2128 driver. The driver receives pulse signal sent out by the controller and transforms it into strong current signals to drive the stepper motor.

Vertically oscillating mechanical transmission mechanism is a crank-link mechanism, as shown in Fig. 1. The motor drives the wheel to rotate at a uniform speed, which drives the bottom vibration body threaded connected to the bottom of link-2 to do simple harmonic vibration vertically. The vibration frequency is controlled by the motor, and the vibration amplitude is adjusted by changing the distance between hinge 1 and the center of the wheel.

Several kinds of rigid equilateral prisms were used as vibration source, including triangular prism, quadrangular column, hexagonal column, and cylinder, etc (Fig. 2). In order to ensure the identical experimental driving force, each structure is 40 mm thick and 5 000 mm^2 in area, and made of industry standard aluminum molding.

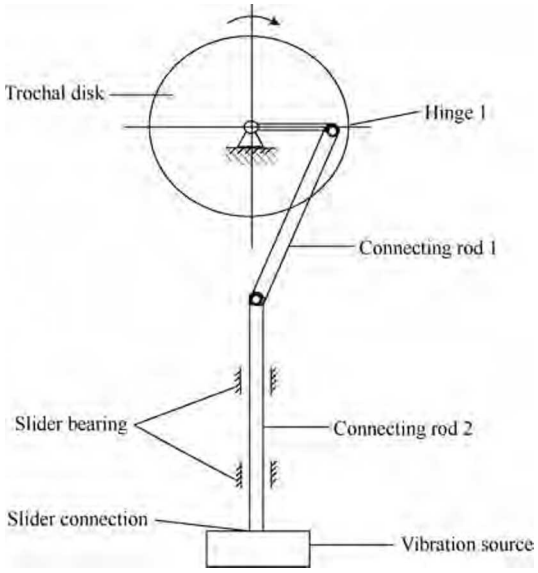

Fig. 1. Vertical oscillating mechanical transmission.

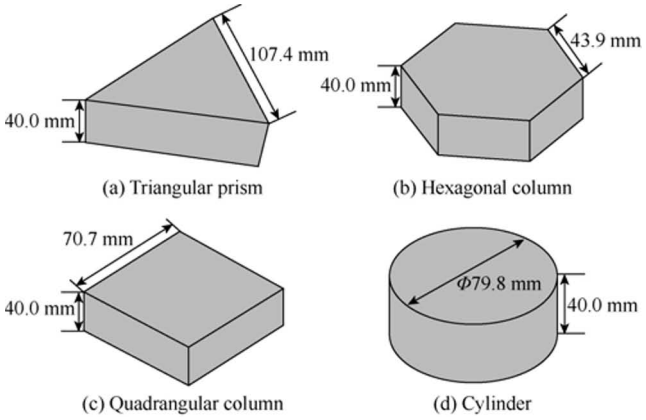

Fig. 2. Vibration sources in various regular prism shapes.

The pool in the experiment was 800×800 mm, with water depth of 500 mm. The inner walls of the pool was coated with a thin layer of sponge to reduce the boundary effect; the floater was made of thin plastic 10 mm in diameter. First, the floater was put in water about 100 mm horizontally away from the centroid of the vibration source, facing the edge or the facet of the vibration prism respectively; then the float's movement caused by surface wave sent out from different vibration columns in the same condition was observed (the entering depth 20 mm, the vibration frequency 1 Hz, the amplitude ± 15 mm, vertical harmonic vibration).

To better observe and record the surface wave characteristics caused by different vibration source, the experimental process was video recorded by the camera, and the tracking analysis software TRACKER was taken to analyze the movement and wave characteristics of the floater.

2. Results and discussion

In this paper, repeated experiments were carried out to examine the fluid surface waves caused by vibration sources of different structures (no less than 20 times). The high repeatability of experiment data indicates the system is stable and the data is reliable in the experiment. Directional attraction or repellency has emerged before waves reached the wall in each experiment, indicating the boundary effect in the experiment pool was not obvious.

2.1. Vibration source in triangular prism shape

Fig. 3 shows the distance between the floater facing the facet of the triangular prism and the centroid of vibration source, obtained from analyzing video data in the experiment with the TRACKER software, it can be seen after the beginning of vibration, the floater started to get away from the vibration source, the relationship between displacement and time was almost linear. The result is consistent with the common knowledge that the surface wave caused by the vibration source would reject the floater outwards.

Fig. 4 shows the distance between the floater placed on the water surface facing the edge of the triangular prism and the centroid of vibration source with time. With the beginning of vibration, the floater started to move directly to the vibration

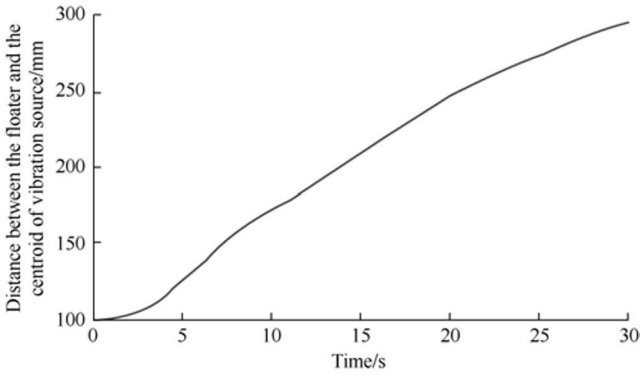

Fig. 3. Rejection of the floater facing the facet of the triangular prism.