AN EXPERIMENTAL STUDY OF A SOLITARY WAVE IMPACTING A VERTICAL SLENDER, CIRCULAR CYLINDER

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1. INTRODUCTION

Solitary waves can evolve into plunging breakers during shoaling, inducing high wave loads on coastal structures. Meanwhile, plunging waves propagate with rapid spatial-temporal variations both in wave geometry and wave kinematics, causing varying forces on structures for different breaking stages (Chan et al., 1995). Although there have been numerous experiments for wave forces on cylinders, to our knowledge no experiments have studied the forces at different breaking stages of a plunging solitary wave. Thus, in our study, experiments are conducted to investigate the force due to a plunging solitary wave impacting a circular cylinder as a function of the wave's phase. Due to these forces, as expected structural responses are induced (Paulsen et al., 2019); to eliminate the effect of the structural response, the equation of motion is proposed to facilitate extracting only the isolated hydrodynamic forces.

2. EXPERIMENTS

The experiments are conducted in a wave flume located at the State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology. The flume used is 22 m long and 0.45 m wide with a uniform water depth of 0.20 m (except in the region of the bar).

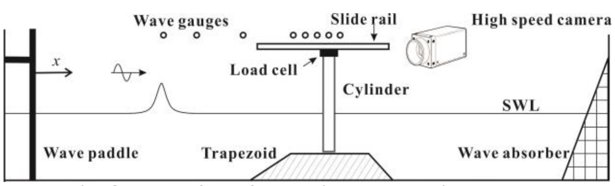

Figure 1 - Sketch of the facility (not to scale).

A solitary wave with height 0.13 m is generated based on the third-order solitary wave theory. A spanwise, asymmetric trapezoidal bar is located roughly halfway downstream to cause shoaling, while a vertical cylinder with 0.06 m diameter is placed above the flat portion of the bar (see Figure 1). The top of the cylinder is connected to a force transducer which is fixed to a slide. The slide is mounted onto a rigid frame along which the cylinder's positions can be determined, thus eliminating much of the interaction the structure has on the wave. Besides inline forces measured by a load cell attached to the fixed structure, wave elevations are measured by wave gauges. Additionally, a high speed camera is used to capture sea surface profiles (see Figure 2).

3. RESULTS AND DISCUSSION

Figure 2 presents the measured force F_{meas} (black curve) and hydrodynamic force F_{hydro} (red dashed line) for the experimental case with the cylinder 9.30 m from the wave paddle. In Figure 2, F_{hydro} exhibits no oscillations, which indicates the successful removal of the inline structural response. To extract F_{hydro}, the equation of motion is used and surface elevations are considered to determine properties of the cylinder (see Figure 3). Figure 4 shows the peak values for F_{meas} and F_{hydro} as a function of breaking phases. Results show that as the plunging solitary wave continues to propagate, the maximum hydrodynamic force increases until it reaches its highest value (i.e. when the wave tongue is curling down but prior to its impingement on the free water surface), which is followed subsequently by a decrease. This trend is found also in the measured force.

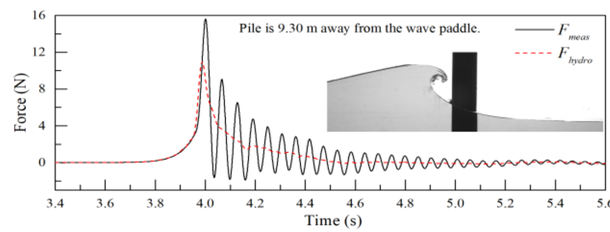

Figure 2 - F_{meas} and its corresponding F_{hydro} on the cylinder.

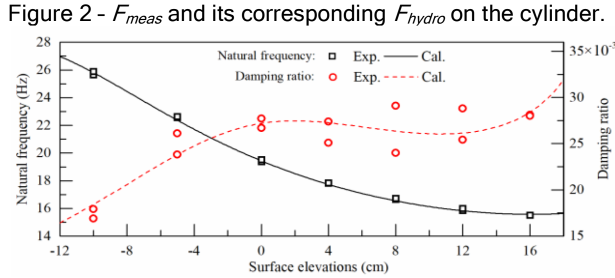

Figure 3 – Cylinder's properties to different surface elevations.

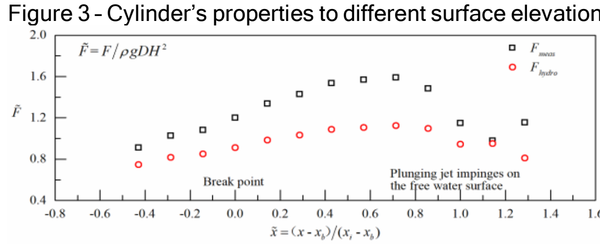

Figure 4 - The maximum F_{meas} and F_{hydro} as a function of the breaking phases.

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