Interaction between Solitary Wave and Flexible Plate based on MPS-FEM coupled Method

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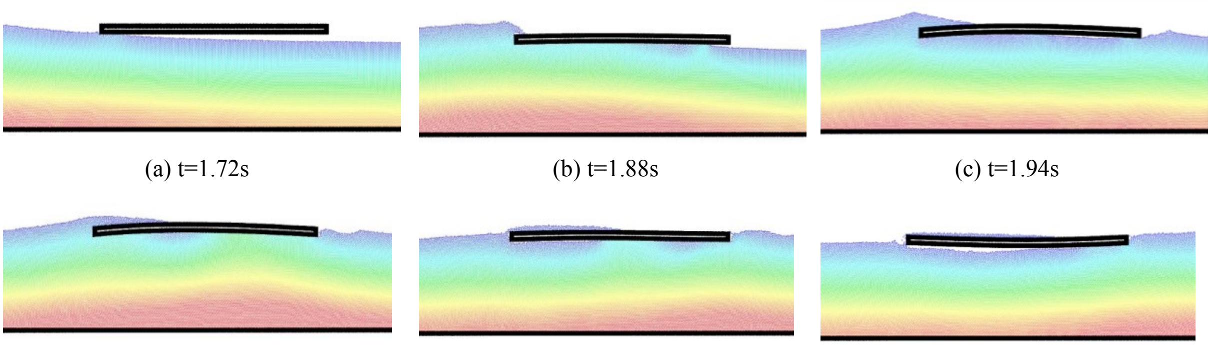
Abstract: The model of wave interacting with the plate is commonly seen in the offshore and coastal engineering. For example, a very large floating structure (VLFS) with its horizontal size much greater than the vertical size is usually treated as thin plate floating in the ocean. While encountering severe wave, it could produce considerable deformation which will exert a great influence on the flow field nearby, making the problem more complex. To conduct the FSI analysis of the wave-plate interaction problem, the Moving Particle Semi-Implicit and finite element coupled method (MPS-FEM) is proposed. The MPS method is adopted to calculate the fluid domain while the structural domain is solved through FEM method.

The solitary wave is first generated in a numerical wave tank and then be compared with the theoretical wave profile. The convergence study with regard to particle resolution is conducted to find the appropriate particle spacing employed in the following simulations. Then the simulations of various solitary wave impacting onto flexible plate are conducted. To validate the accuracy of the current FSI solver, the wave-induced force on the plate is compared with the existent experimental result, which shows a good agreement. The effects of the structural deformation on the flow is investigated. It turns out that the vibration of the flexible plate may intensify the impact with the free surface. In addition, the maximum displacement on the middle-point of the plate under wave with various amplitude is collected to examine quantitatively the structural response to the impact.

KEY WORDS: Moving Particle Semi-implicit (MPS); Finite element method (FEM); Fluid-structure interaction (FSI); Solitary wave; Plate structure



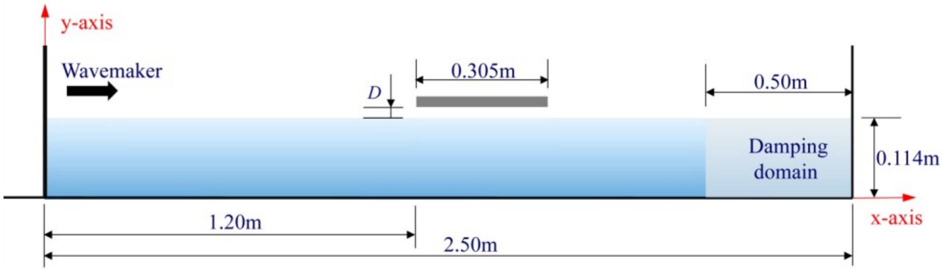
(a) t=1.72s (b) t=1.88s (c) t=1.94s

(d) t=2.06s (e) t=2.12s (f) t=2.20s

Figure 1- Snapshots of the wave-plate interaction

Numerical simulations

The interaction between the solitary wave and a horizontal plate is simulated using the in-house solver in this section. The geometric model of the wave flume, as well as the horizontal plate, is depicted in Fig. 1. The wave flume has its length of 2.5 meters and water depth (H) of 0.114 meter.



Numerical wave generation

The accuracy of the wave generation is crucial in the problems of wave-structure interaction. In this sub-section, the wave generation is conducted in the numerical wave flume without the plate to examine the accuracy of the generated solitary wave. Different wave amplitudes (A), including A/H=0.2, 0.3, 0.4 and 0.5, are adopted in the simulations. The computational parameters are listed in Table 1.

Table 1. Computational parameters

Parameter	Value
Water density	1000(kg/m^3)
Water depth	0.114(m)
Kinematic viscosity	1×10^{-6}(m^2/s)
Gravitational acceleration	9.81(m/s^2)
Particle spacing	0.002(m)
Fluid number	71193
Total number	75762

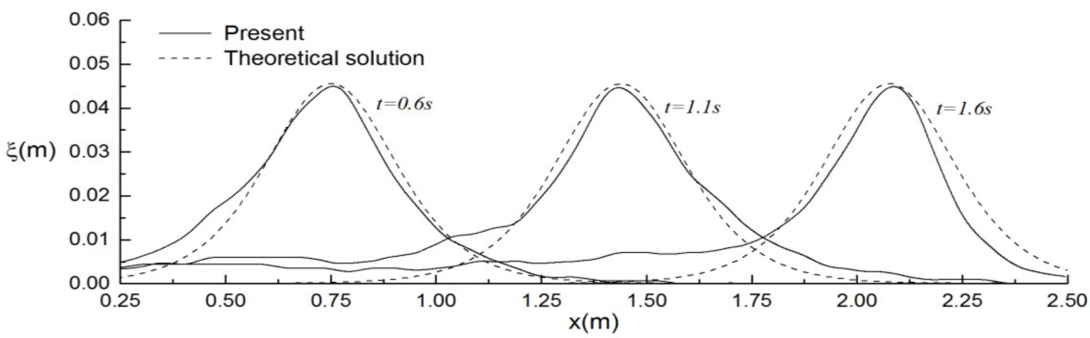


Fig. 2 shows the comparison of the wave profile between the numerical simulation and the theoretical solution. It can be seen that the wave crest of the simulation agree well with the theoretical solution. Besides there is no evident decay in the wave crest as it propagates downstream. However there are still some slight distinctions, such as in the ascending portion of the curve, owing to the finite length and depth of the wave tank. It can be concluded that desired solitary wave can be generated based on MPS method.

Interaction between wave and rigid plate

The interaction between the solitary wave and a rigid plate is simulated in this sub-section. The plate is placed at the position of 1.2 meters from the wavemaker. And the size of clearance between the bottom of the plate and the still water line (SWL) is defined as *D*, which can be altered by moving the plate. In the simulations, the size of clearance (*D*) and wave amplitude (*A*) vary in different cases in order to investigate their effects on the wave-induced force on the plate. The dimensionless parameters of all the cases are shown in Table 2.

No.	Amplitude (A/H)	Clearance (D/H)	No.	Amplitude (A/H)	Clearance (D/H)
1	0.2	0.03	7	0.4	0.03
2	0.2	0.06	8	0.4	0.06
3	0.2	0.1	9	0.4	0.1
4	0.3	0.03	10	0.5	0.03
5	0.3	0.06	11	0.5	0.06
6	0.3	0.1	12	0.5	0.1