RIP CURRENT FORMATION: IMPROVING BOUSSINESQ MODEL WITH MODIFIED BOUNDARY

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1. INTRODUCTION

Rip currents are thought to be important hydrodynamic action for water and sediment between the surf zone and the outer nearshore. This currents are distinguish by three characteristic: 1)they are driven by longshore variations in wave height 2)they exhibit periodic fluctuations in time and are often periodically spaced in the longshore direction and 3)they increase in strength with increasing wave height [Haller, 1997]. Rip currents influence the morphology of the shoreline and important for transporting fine sediments offshore. This strong and pulsation current also incorporated with rhythmical shoreline such as cusps.

The numerical modeling was simulated with a Boussinesq model using a model version of *Funwave*, a code developed by The Center for Applied Coastal Research, University of Delaware.

The present study provides direct comparison with laboratory data from the measurement conducted by Haller [1997]. Bottom topography of basin was intended to be planar and two rip channels were symmetric and equal each other as shown in **Figure 1**.

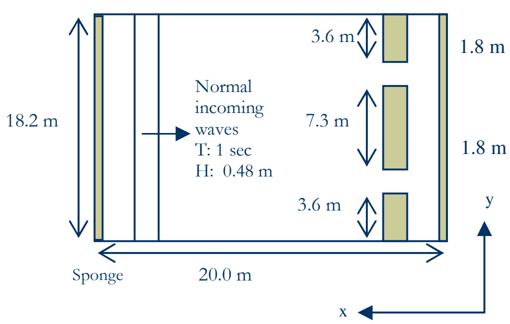

***Figure 1**. Basin with submerged sandbar*

The horizontal variations of rip current systems with Boussinesq model are simulated. Nearshore circulation system which dominated due to longshore variations is clearly shown. The growth of rip current system is shown by the snapshots of vorticity and velocity contour. Analysis result from time averaged of surface water elevation, cross-shore current and longshore current velocities throughout rip current systems in general shows agreement [Kurniadi, 2007]. However, the time averaged of physical variable near shoreline boundary is not modeled very well.

Therefore the boundary near the shoreline is adjusted for a better computation. Formation of rip current are driven by longshore current which reflected by shoreline boundary. Run up action at shoreline is included in this model. When this action is included, flow reflection from swash zone could be contributed as a net flow in the surf zone. Flow interaction between swash zone and surf zone will be well examined. In this paper we present Boussinesq model which improved with an additional term in the shoreline boundary condition.

2. BOUSSINESQ MODEL IMPLEMENTATION

Boussinesq equation is the non-linear amplitude wave theory which used to analyze the variations of wave height and current in surf zone. The conservation of mass is defined as

$$\beta\eta_t + \nabla\cdot M = 0 \qquad (1)$$

with M stands for,

$$M = (h+\eta)\left[u_\alpha + \left(z_\alpha + \frac{1}{2}(h-\eta)\right)\nabla(\nabla\cdot(hu_\alpha))\right] + \left(\frac{z_\alpha{}^2}{2} - \frac{1}{6}(h^2 - h\eta + \eta^2)\right)\nabla[\nabla\cdot(u)hu] \qquad (2)$$

where η is the surface elevation, h is the still water depth, u_α is the horizontal velocity vector at the water depth $z = z_\alpha = -0.531h$, $\nabla = (\partial/\partial x + \partial/\partial y)$ is the horizontal gradient operator, g is the gravitational acceleration, and subscript t is the partial derivative with respect to time. The governing equation is expressed at reference depth as a dependent variable.

The conservation of momentum is

$$u_t + (u\cdot\nabla)u + g\nabla\eta + V_1 + V_2 + V_3 - F_{br} - F_m + F_b = 0 \quad (3)$$

where terms V for dispersive and F_{br}, F_m, and F_b are for wave breaking, lateral momentum fixing and bottom friction.

3. MOVING SHORELINE BOUNDARY

Shoreline boundaries may move significantly under the temporal influence of incident waves. A numerical model should be able to take into account such variations correctly in order to obtain realistic flow patterns. To examine wave run up /run down on the shoreline, the entire computational domain treat as an active fluid domain by improving the slot for simulation of run up. The basic idea behind this technique is to replace the solid bottom where there is very little or no water covering the land by a porous seabed, or to assume that the solid bottom contains narrow slot. The replacement of the solid bottom by narrow slot will result in a modification of the mass equation.

Rewrite equations (1) and (3), surface elevation at equation (1) will describe as

$$\eta_t = E(\eta, u, v) \qquad (4)$$

with E stands for

$$E = -\frac{1}{\kappa}\left[(\Lambda u)_x + (\Lambda u)_y\right] - \left\{a_1h^3(u_{xx} + v_{xy}) + a_2h^2((hu)_{xx} + (hv)_{xy})\right\}_x - \left\{a_1h^3(u_{xy} + v_{yy}) + a_2h^2((hu)_{xy} + (hv)_{yy})\right\}_y \qquad (5)$$

Here u and v are the horizontal velocities in horizontal directions x and y at reference depth. Constant a_1, and a_2 are related to dimensionless reference water depth $\beta = -0.531$ by $a_1 = 0.5\beta^2 - 0.167$ and $a_2 = \beta + 0.5$.
Slot parameter defined as

$$\kappa = \begin{cases} \delta + (1-\delta)e^{\lambda\frac{(\eta - z^*)}{h_0}} , & \eta \le z^* \\ 1 , & \eta > z^* \end{cases} \qquad (6)$$

and

$$\Lambda = \delta(\eta + h_0) + \frac{(1-\delta)h_0}{\lambda}\left(e^{\lambda\frac{(\eta - z^*)}{h_0}} - e^{-\lambda\frac{(h_0 - z^*)}{h_0}} \right), \eta \le z^* \qquad (7)$$

$$\Lambda = (\eta - z^*) + \delta(z^* + h_0) + \frac{(1-\delta)h_0}{\lambda}\left(1 - e^{-\lambda\frac{(h_0 - z^*)}{h_0}} \right), \qquad \eta > z^* \qquad (8)$$

The reference z^* is the elevation of the solid bed and can be expressed as

$$z^* = \frac{z^s}{1-\delta} + h_0\left(\frac{\delta}{1-\delta} + \frac{1}{\lambda} \right) \qquad (9)$$

Here δ is the relative width of a slot with respect to unit width of beach. The value are could be adjust between 0.002 until 0.02. Parameter λ is for smooth transition from unity value to δ, and h_0 is the offshore water depth where the slot begins. Value of λ could be adjust from 20 until 80.
Modification of those slot parameters will give a better result for understanding run up action in the shoreline boundary.

4. RESULT AND DISCUSSION

Data which conducted in the laboratory [Haller et al, 1997] was measured with ADV, acoustic doppler velocity meter. Direct comparisons between experiment and model are only possible for the time averaged quantities. Time averaging result must be considered the warm-up period. The warm-up period is a period where the boundary conditions gradually are built up to a prescribed value. A warm-up period used to avoid blow-ups during the first time steps. In this numerical calculation, the warm-up period is count from 1000 time step.

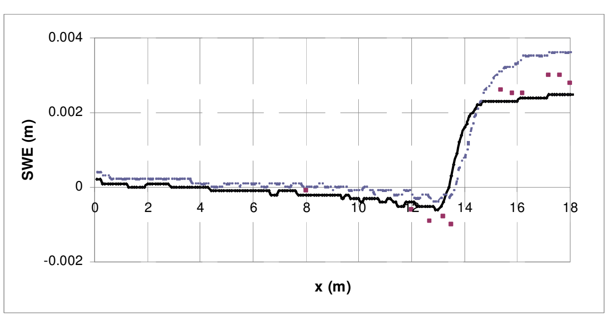

***Figure 2**. Time averaged of surface elevation with slot (solid line) ,without slot (dash line) and measurement data (dot)*

Comparison the cross-shore variation of time averaged surface water elevation result within model with and without slot parameter is shown in **Figure 2**. Model result with slot parameter gives a better agreement in the shoreline boundary.

When waves break on a beach, they produce a set-up, or rise in the mean water level above the still water level. Wave height and period variations among incoming waves cause the water level in the surf zone to have areas of non-uniformity. This varying of high and low set-up causes a horizontal pressure gradient that induces the current flow from the high to low set-up areas. From numerical result, it is clearly shown that the presence of submerged sandbar could raise the wave setup which creating variation of wave setup area. High wave setup area will results in longshore pressure gradient which flow away from behind the bar to the channel and form circulation cell, known as rip current. Circulation formation is highly dependent on the breaking pattern. Time averaged of flow pattern is shown in **Figure 3**. The flow from model result seems similar with measurement data from Haller et al. By applying slot parameter on the shoreline boundary, will gives a symmetric flow pattern in both rip channels.

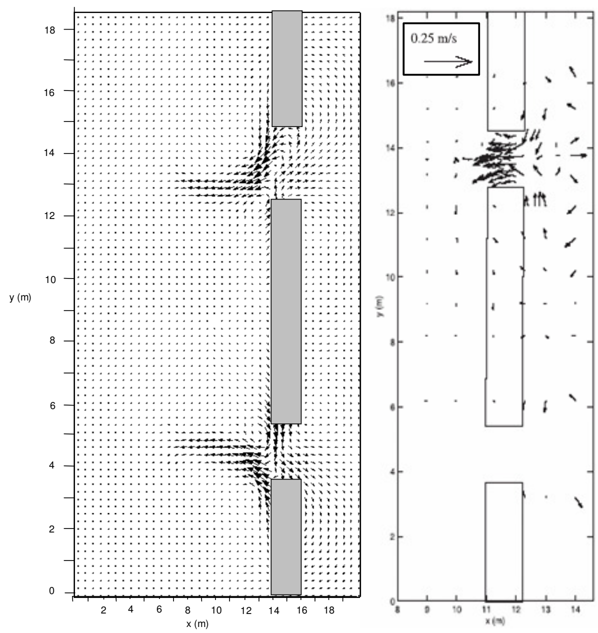

***Figure 3**. Time averaged mean current flow pattern Numerical result (left), measurement data (right)*

5. CONCLUSION

Slot parameter, one of moving boundary technique has been applied to shoreline boundary in numerical model for a better computation. This technique could describe run up action in swash zone. Rip current modeling with improving Boussinesq model by applying slot parameter has been examined.

REFERENCES

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