

Simulation of Canal Control-Gates Operations Using Hydrodynamic Model

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Abstract

In this research, hydraulic effects of canal control-gates operations have been simulated using hydrodynamic model. A few tests were performed with four slide gates in the laboratory canal equipped by sensitive instruments for measuring and saving the time variation of the water depths. The measured depths were compared with the hydrodynamic model simulation results. Average error of the model estimation along the canal was 0.60% for gradually opening changes and 3.74% for sudden opening changes of the control gates. The results showed that the hydrodynamic model based on the implicit F.D.M of the unsteady flow equations would be able to simulate the gradually operation of control gates with good accuracy. This model can be used for different purposes such as design of control systems in water conveyance canals.

Key words: Control gates, Canal, Simulation, Unsteady flow.

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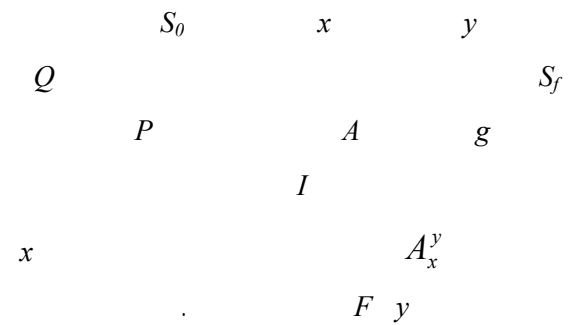
$$\frac{dy}{dx} = [S_0 - S_f - \frac{2Q}{gA^2}P + \frac{1}{gA}(\frac{Q^2}{A^2})A_x^y] / (1 - F^2) \quad ()$$

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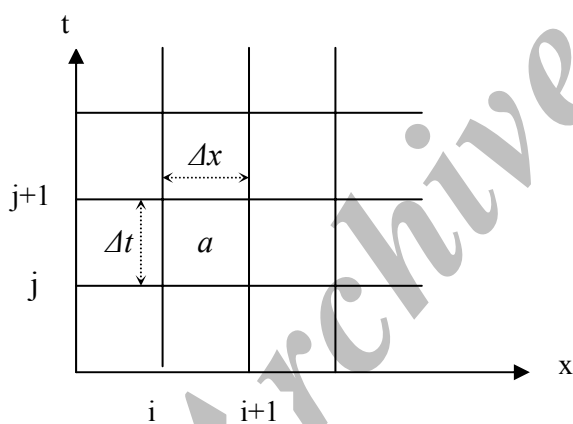
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$$\frac{dy}{dx} = [S_0 - S_f - \frac{Q}{gA^2}I + \frac{1}{gA}(\frac{Q^2}{A^2})A_x^y] / (1 - F^2) \quad ()$$

$$y_i^{k+1} = y_i^k - \frac{f(y_i^k)}{f'(y_i^k)} \quad (1)$$



$$\frac{\partial y}{\partial t} + \left(\frac{A}{B}\right) \frac{\partial V}{\partial x} + V \frac{\partial y}{\partial x} + \frac{V}{B} (A_x^y) - \frac{1}{B} (P - I) = 0 \quad (2)$$



$$\frac{\partial V}{\partial t} + V \frac{\partial V}{\partial x} + g \frac{\partial y}{\partial x} + g(S_f - S_0) + \frac{V}{A} (P - I) = 0 \quad (3)$$

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$$y(a) = \frac{\theta}{2} (y_{i+1}^{j+1} + y_{i+1}^{j+1}) + \frac{1-\theta}{2} (y_i^j + y_{i+1}^j) \quad (4)$$

$$\frac{\partial y(a)}{\partial x} = \theta \left(\frac{y_{i+1}^{j+1} - y_{i+1}^{j+1}}{\Delta x} \right) + (1-\theta) \left(\frac{y_{i+1}^j - y_i^j}{\Delta x} \right)$$

$$f(y_i) = -y_{i+1} + y_i - \frac{\Delta x}{2g} I \left(\frac{Q_{i+1}}{A_{i+1}^2} + \frac{Q_i}{A_i^2} \right) + \frac{Q_{i+1}^2}{2g}$$

$$\left(\frac{1}{A_{i+1}^2} - \frac{A_i}{A_{i+1}^3} \right) + \frac{Q_i^2}{2g} \left(\frac{A_{i+1}}{A_i^3} - \frac{1}{A_i^2} \right)$$

$$- (Z_{i+1} - Z_i) - \frac{\Delta x n^2}{2} \left(\frac{Q_{i+1}^2 P_{i+1}^{4/3}}{A_{i+1}^{10/3}} + \frac{Q_i^2 P_i^{4/3}}{A_i^{10/3}} \right) \quad (5)$$

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 Z , P_i

$$C_7 = \frac{\Delta t}{\Delta x} C_5 C_6 \quad ()$$

$$C_8 = \Delta t \cdot q(1-\theta) \left[\left(\frac{1}{B} \right)_{i+1}^j + \left(\frac{1}{B} \right)_i^j \right] \quad ()$$

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$$G_i(y_i^{j+1}, V_i^{j+1}, y_{i+1}^{j+1}, V_{i+1}^{j+1}) = \frac{1}{g} \frac{\Delta x}{\Delta t} (V_{i+1}^{j+1} + V_i^{j+1})$$

$$+ C_9 + \frac{\theta^2}{g} \left[(V_{i+1}^{j+1})^2 - (V_i^{j+1})^2 \right]$$

$$+ C_{10} \frac{\theta}{g} (V_{i+1}^{j+1} - V_i^{j+1}) + C_{11} \frac{\theta}{g} (V_{i+1}^{j+1} + V_i^{j+1})$$

$$+ C_{12} + 2\theta (y_{i+1}^{j+1} - y_i^{j+1}) + C_{13} + C_{14}$$

$$+ \Delta x \theta \left[(S_f)_{i+1}^{j+1} + (S_f)_i^{j+1} \right] +$$

$$C_{15} + q \frac{\Delta x}{g} \theta \left[\left(\frac{V}{A} \right)_{i+1}^{j+1} + \left(\frac{V}{A} \right)_i^{j+1} \right] + C_{16} = 0 \quad ()$$

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$$C_9 = -\frac{1}{g} \frac{\Delta x}{\Delta t} (V_{i+1}^j + V_i^j) \quad ()$$

$$C_{10} = (1-\theta) (V_{i+1}^j + V_i^j) \quad ()$$

$$C_{11} = (1-\theta) (V_{i+1}^j - V_i^j) \quad ()$$

$$C_{12} = \frac{(1-\theta)^2}{g} \left[(V_{i+1}^j)^2 - (V_i^j)^2 \right] \quad ()$$

$$C_{13} = 2(1-\theta) (y_{i+1}^j - y_i^j) \quad ()$$

$$C_{14} = 2(z_{i+1}^j - z_i^j) \quad ()$$

$$C_{15} = \Delta x (1-\theta) \left[(S_f)_{i+1}^j + (S_f)_i^j \right] \quad ()$$

$$C_{16} = q \frac{\Delta x}{g} (1-\theta) \left[\left(\frac{V}{A} \right)_{i+1}^j + \left(\frac{V}{A} \right)_i^j \right] \quad ()$$

$$(S_f)_i^j = \frac{(n_i^j)^2 V_i^j |V_i^j| (P_i^j)^{4/3}}{(A_i^j)^{4/3}} \quad ()$$

$$() \quad ()$$

$$\frac{\partial y(a)}{\partial t} = \frac{1}{2} \left(\frac{y_{i+1}^{j+1} - y_{i+1}^j}{\Delta t} \right) + \frac{1}{2} \left(\frac{y_i^{j+1} - y_i^j}{\Delta t} \right) \quad ()$$

$$\Delta t \quad \Delta x \quad \theta$$

$$V^{j+1}, V^j, y^{j+1}, y^j$$

$$F_i(y_i^{j+1}, V_i^{j+1}, y_{i+1}^{j+1}, V_{i+1}^{j+1}) = (y_{i+1}^{j+1} + y_i^{j+1}) +$$

$$C_1 + \frac{\Delta t}{\Delta x} \theta^2 \left[\left(\frac{A}{B} \right)_{i+1}^{j+1} + \left(\frac{A}{B} \right)_i^{j+1} \right] (V_{i+1}^{j+1} - V_i^{j+1})$$

$$+ \frac{\Delta t}{\Delta x} \theta C_2 (V_{i+1}^{j+1} - V_i^{j+1}) + \frac{\Delta t}{\Delta x} \theta C_3 \left[\left(\frac{A}{B} \right)_{i+1}^{j+1} + \left(\frac{A}{B} \right)_i^{j+1} \right] +$$

$$C_4 + \frac{\Delta t}{\Delta x} \theta^2 (V_{i+1}^{j+1} + V_i^{j+1}) (y_{i+1}^{j+1} - y_i^{j+1})$$

$$+ \frac{\Delta t}{\Delta x} \theta C_5 (y_{i+1}^{j+1} - y_i^{j+1}) + \frac{\Delta t}{\Delta x} \theta C_6 (V_{i+1}^{j+1} + V_i^{j+1}) +$$

$$C_7 - \Delta t \cdot q \theta \left[\left(\frac{1}{B} \right)_{i+1}^{j+1} + \left(\frac{1}{B} \right)_i^{j+1} \right] - C_8 = 0$$

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$$C_1 = -(y_{i+1}^j + y_i^j) \quad ()$$

$$C_2 = (1-\theta) \left[\left(\frac{A}{B} \right)_{i+1}^j + \left(\frac{A}{B} \right)_i^j \right] \quad ()$$

$$C_3 = (1-\theta) (V_{i+1}^j - V_i^j) \quad ()$$

$$C_4 = \frac{\Delta t}{\Delta x} C_2 C_3 \quad ()$$

$$C_5 = (1-\theta) (V_{i+1}^j + V_i^j) \quad ()$$

$$C_6 = (1-\theta) (y_{i+1}^j - y_i^j) \quad ()$$

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$$- (S_f)_i^j \text{ و } n_i^j, P_i^j, B_i^j, A_i^j .$$

$$A_x^y = 0$$

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$$F_i(y_i^{j+1}, V_i^{j+1}, y_{i+1}^{j+1}, V_{i+1}^{j+1}) = 0, i = 1, \dots, N$$

VisiDAQ

$$G_i(y_i^{j+1}, V_i^{j+1}, y_{i+1}^{j+1}, V_{i+1}^{j+1}) = 0, i = 0, \dots, N-1$$

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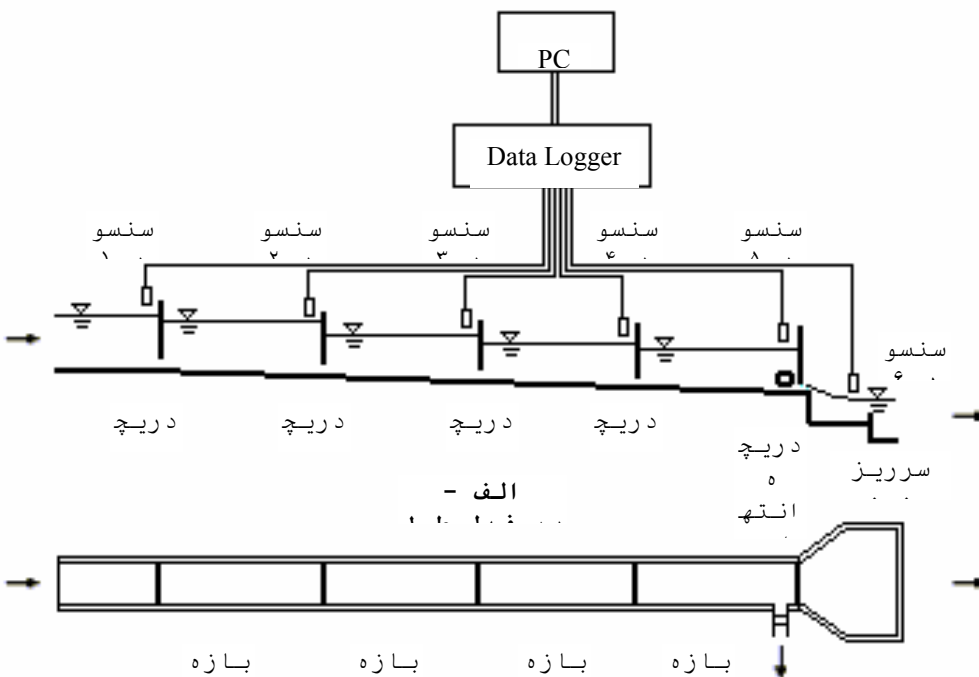
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$$RMSE = \left[\frac{1}{n} \sum_{i=1}^n (y_{oi} - y_{ci})^2 \right]^{0.5} \quad ()$$

$$RAE = \frac{\sum_{i=1}^n | (y_{oi} - y_{ci}) |}{\sum_{i=1}^n y_{oi}} \quad ()$$

y_{oi} y_{ci}

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RMSE

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- 1- Root mean square of error
 - 2- Relative average error

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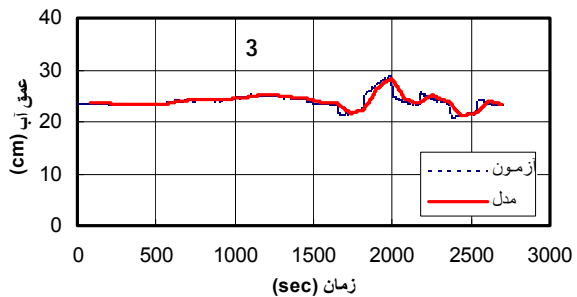
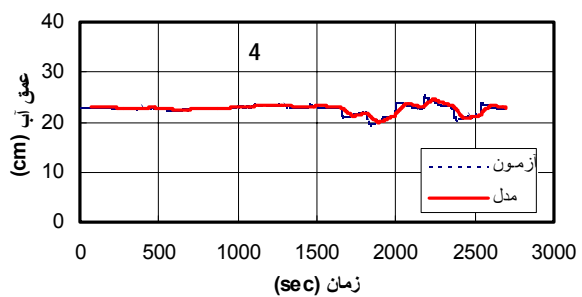
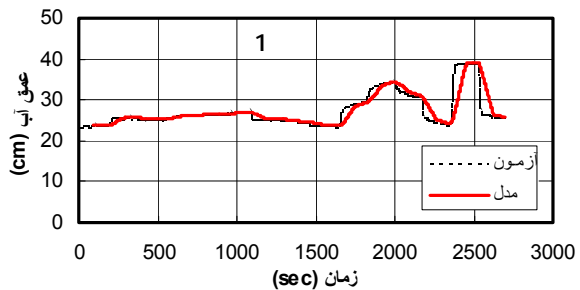
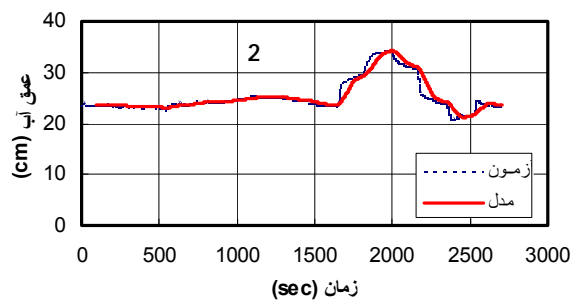
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