Guide for ChuteAer Code for calculating flow characteristics over chute spillways including air entrainment

When water flows over chute spillways, the self-aeration phenomena occurs downstream of the inception point, at which the turbulent boundary layer edge approaches the free surface. Downstream of the inception point, an air-water mixture layer develops gradually through the flow with the bulking effect. The Introduction of enough air near the solid boundary prevents cavitation damage. Studying flow bulking is also essential in terms of sidewall freeboard design.

In the present code, a two-dimensional mathematical model is developed to predict the self-aeration phenomena, free-surface flow location, velocity and air concentration distribution, and flow bulking effect in smooth chutes (Jalili Ghazizadeh et al., 2022). The model is developed by solving the one-way direction parabolic equations of mixture continuity, air mass, air-water mixture momentum conservation, together with the dynamic equation for defining the free surface, utilizing the Marching Technique and Prandtl's Mixing Length turbulent model. More information about the present code can be found in (Jalili Ghazizadeh et al., 2022).

The code has been written in the Fortran programing language with the Power Station compiler.

Descriptions of the Entry and results directories, which includes input and output files and a list of the used subroutines in the main program, are as follows:

- **Entry Directory**: consists of; 1- Name file 2-input file.
  User selects an arbitrary name for his/her input file and writes the chosen name in the Name file (with ".in" extension). All input parameters must be provided in the input file. An example input file is given at the end of this guildline. The input file name in this example is "Data.in".

  In "Data.in" file, the input parameters are also described (see Entry\Data.in)

- **Results Directory:** The main program saves the output results in the "Results" directory. There are three different outputs files as follows:
  - ✓ Output_a: gives results of the water-free surface along the channel.
  - ✓ Output_b: gives results of air concentration and velocity distributions across the depth for the different sections.
  - ✓ Output_c: prepares data for the Tecplot software.

In the main program, there are 17 subroutines, as shown in Table 1.

Table 1. List of the subroutines in the main program

Number	Subroutine name	Description
1	INPUT	Assigning the input values to the model parameters
2	INITIALC5	Calculating the initial conditions (the first boundary condition)
3	UMOMENTUM	Solving the U momentum equation

Number	Subroutine name	Description
4	TDMA	Solving the systems of equations using the Tridiagonal Matrix Algorithm (TDMA)
5	DEPTH	Calculating flow depth and z coordinate of computational cells
6	PRESSURE	Calculating nodal pressure
7	JUDGE	Comparing the convergence criteria
8	SUBSTITUTION	Substitute "k+1" th section with the "k" th section based on the Marching technique
9	WARNING	Sending divergence warnings
10	CONTINUITY	Solving the continuity equation to calculate the v parameter
11	MIXINGLENGTH	Implement the Mixing Length turbulence model
12	ROW-CALCULATION	Calculating the air-water density
13	C- CALCULATION	Calculating the air volume concentration
14	TECPLOT	Preparing data for Tecplot software
15	RISING VELOCITY	Calculating the rising velocity
16	OUTPUT	Report the outputs data
17	CONVECTION-DIFFUSION 5	Solving the convection-diffusion equations

Example:

This example is about the simulation of flow and self-aeration on Aviemore dam. Different prototype measurements were conducted on the Aviemore dam chute spillway by Cain (1978). The Aviemore chute spillway is initiated by a radial gate and an ogee profile and continues to a 45º steep sloping chute. These measurements include the free surface longitudinal profile and air concentration distribution in depth downstream of the inception point along the spillway chute (Cain 1978; Cain and Wood 1981).

Let’s consider the input parameters for the 0.45m gate opening case, as follows:

Water Flow Discharge: 3.150 m^3/s

Initial Flow Depth: 0.250 m

Channel Slope: 45 degree

Number of Cells in Depth: 25

Mesh Size in the Stream-wise Direction: 0.01m

Domain Length: 40 m

Reference Residual for Discharge: 0.01m^3/s

The output files can be found in the Results directory.

The code developers

Dr. Mohammadreza Jalili Ghazizadeh has developed this code under Dr. Zarrati's supervision. If you have any questions or inquiries about the code, please email m_jalili@sbu.ac.ir or zarrati@aut.ac.ir

You are allowed to use this code if you refer to (Jalili Ghazizadeh et al. 2022).

References

Cain, P. (1978). "Measurements within self-aerated flow on a large spillway." PhD, University of Canterbury, Christchurch, New Zealand.

Cain, P., and Wood, I. R. (1981). "Measurements of self- aerated flow on spillways." *Journal of the Hydraulics Division*, 107(11), 1425-1444.

Jalili Ghazizadeh, M. R., Zarrati, A. R., and Ostad Mirza Tehrani, M. J. (2022). "Numerical Modelling of Self-aeration in High-Speed Flows over Smooth Chute Spillways " *Journal of Hydraulic Engineering (ASCE)*, under review.