USING FLUENT AS AN EXPERIMENTAL STAND

FLOW THROUGH A BROKEN BARRAGE

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ABSTRACT

In the paper we propose to use the FLUENT program as experimental stand. Why do we do this? It is often difficult and expensive to achieve a model. It is also difficult to calculate the phenomena in the nature scale using the FLUENT. So we calculated the physical parameters, using FLUENT on the model and we passed them, using the similitude criteria, in the nature. We illustrated the method with a spectacular example: the flow through a broken barrage.

First, we established the model law, taking into account the physical magnitudes which influence the analyzed phenomena. Afterwards we calculated the scales of these physical magnitudes for normal similitude (a single geometrical scale). Using FLUENT we determined the values of the velocity and forces acting on the barrage (the unbroken part). Finally, we passed the "experimental" data in the nature by application of scale for physical magnitudes.

***Keywords**:* similitude, FLUENT, flow through a broken barrage.

1. INTRODUCTION

In many cases, it is very difficult (and expensive) to represent the phenomena in the scale, to achieve a model.

Taking into account the physical magnitudes which influence the analyzed phenomena we can establish the model law.

We use the FLUENT program to calculate the physical magnitudes for the model. Afterwards we pass the data in the nature, using the scales.

FLUENT program acts as experimental stand.

2. THE MODEL LAW

To establish the model law, first we determine the physical magnitudes which influence in the phenomena of flow through broken barrage: h – initial level of water, l – length, Δp - pressure difference, v – fluid velocity, υ - cinematic viscosity of fluid, ρ - fluid density:

$$f\left(h, l, \Delta p, v, \upsilon, \rho,\right) = 0 \tag{1.1}$$

By applying Π theorem, we obtain the similitude criteria:

$$\Pi_1 = \frac{\Delta p}{\rho v^2}; \Pi_2 = \frac{\nu}{vd} = \frac{1}{\mathrm{Re}}; \Pi_3 = \frac{l}{h}; \tag{1.2}$$

and criterial equation:

$$\varphi(\Pi_1, \Pi_2, \Pi_3,) = 0 \tag{1.3}$$

which can be explicitated:

$$\Pi_1 = F(\Pi_2, \Pi_3). \tag{1.4}$$

3. THE SCALES OF PHYSICAL MAGNITUDES

Normal similitude

We consider the scale of length k_l.

$$\begin{gathered} p = \rho g h \\ k_\rho = 1; \\ k_g = 1; \\ k_l = k_h. \\ k_p = k_\rho k_g k_h = k_l \end{gathered} \tag{2.1}$$

We apply the similitude criterion $Fr = \dfrac{v^2}{gl}$.

$$\mathrm{Fr_n} = \mathrm{Fr_m} \Rightarrow \frac{v_n^2}{g_n l_n} = \frac{v_m^2}{g_m l_m} \tag{2.2}$$

Or:

$$\frac{v_n^2}{l_n} = \frac{v_m^2}{l_m} \Rightarrow k_v = \sqrt{k_l} \tag{2.3}$$

The scale of the forces can be established using the formula $F = \gamma V$, where γ is the specific gravity of the fluid. Having the same fluid – water – in the nature and on the model, we can write:

$$k_F = k_l^3 . \qquad (2.4)$$

4. FLUENT MODEL CALCULATION

FLUENT program allow us to simulate an laboratory experiment. Using the similitude theory, we can pass from the model to the nature.

The flow through a broken barrage

The problem of the action of the current is not very simple, especially if we discuss about high velocities (i.e river in the spring time).

Let's presume an experment on the scale 1:25 (k_l = 25) of the flow through a broken barrage:

- symmetrical brakewaters left L = 25 m; l = 2,5 m, h = 12,5 m;
- length of the breach d = 250 m;
- water velocity v = 10 m/s.

By applying Froude similitude, it results:

$\frac{v^2}{gl} = \frac{v'^2}{g'l'}$ (we noted with ' the model magnitudes).

Knowing that g = g', it results th scale of velocity: $k_v = \sqrt{k_l} = 5$.

So v' = 2 m/s. The dimensions of symmetrical brakewaters on the model: L' = 1 m; l' = 0,1 m; h' = 0,5 m. Length of the breach d' = 10 m.

In Fig. 4.1 we have the construction in GAMBIT program of the model:

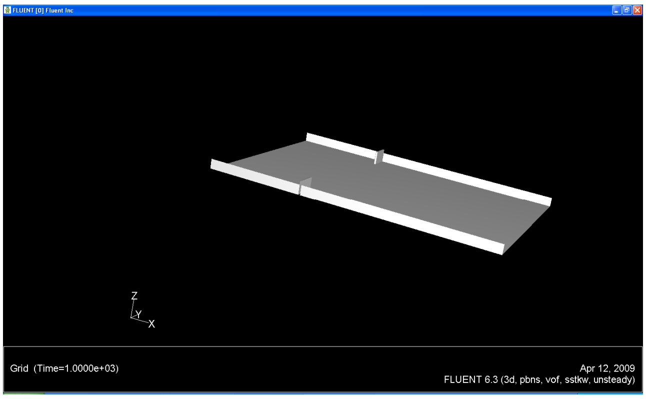

Fig. 4.1 The model of the broken barrage

The discretized model is sent to the FLUENT. First we establish the solving conditions: (Fig. 4.2):

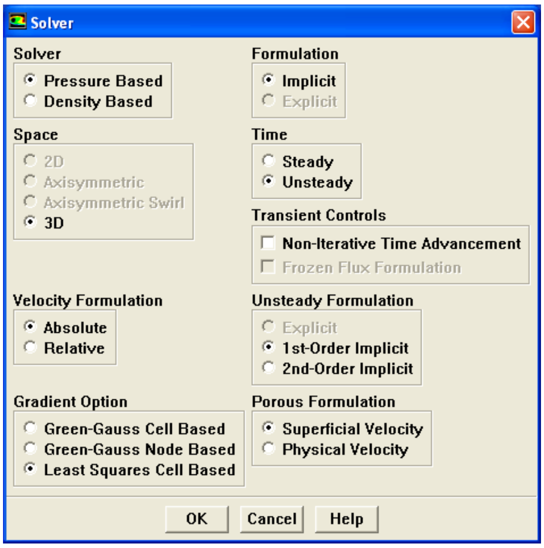

Fig. 4.2 General solving conditions

The solving of the problem is based on pressure notion, implicit formulation. We can notice that we work in 3D, symmetry conditions do not allow to use 2D. We consider the general case of unsteady movement: $\bar{v} = \bar{v}(\bar{r}, t)$.

Very important: we consider the biphasic flow,with free surface.

The calculation begins from entrance velocity, parallel with Ox axis, positive sense (Fig.4.3):

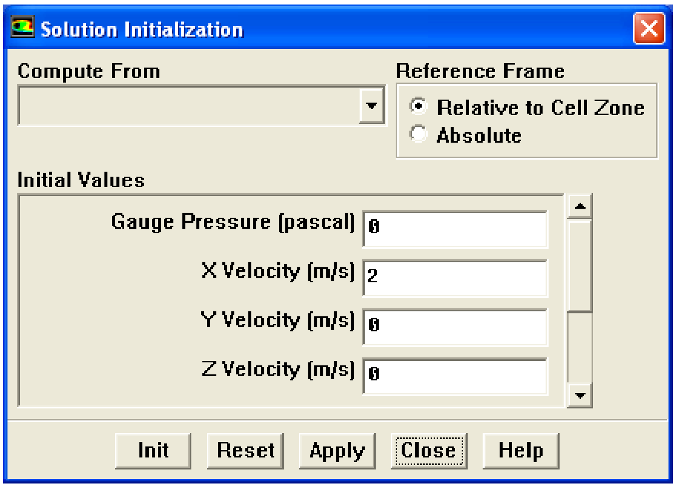

Fig. 4.3 Initialization of solution

Boundary conditions:

- inlet – pressure inlet (velocity: 2 m/s);
- outlet – pressure outlet;
- brakewater – wall;
- symmetry axis – symmetry;
- lateral wall – wall;
- bottom of the water – wall.

After 500 iterations the solution is stabilized and we can see it in different formes:

- grid contour without (Fig. 4.4) and with walls (Fig. 4.5):

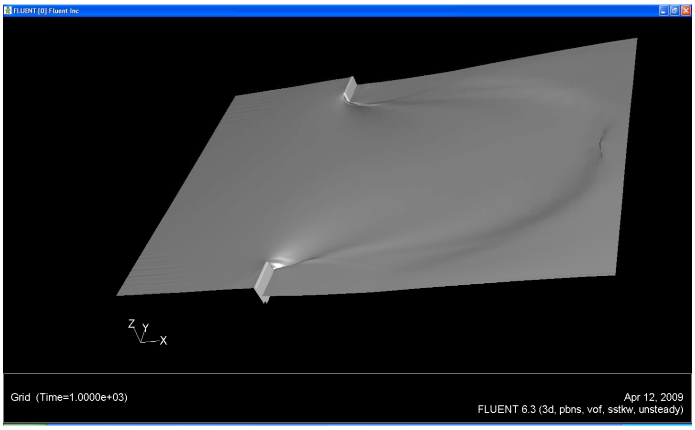

Fig. 4.4 Grid contour without walls

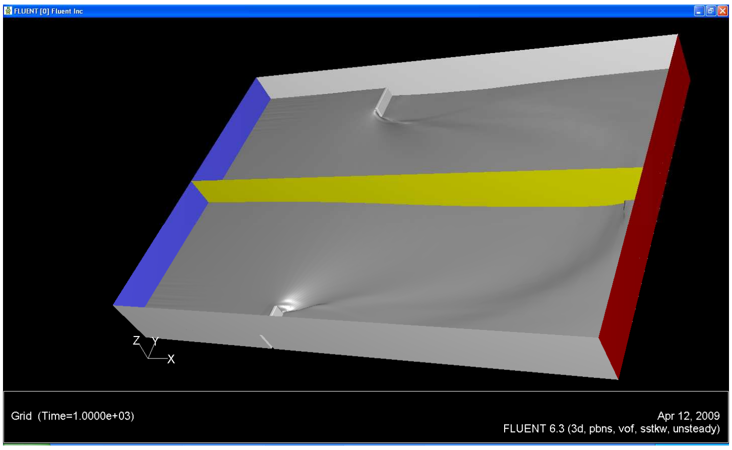

Fig. 4.5 Grid contour with walls and symmetry axis

- contour of velocities (Fig. 4.6) and contour of pressure (Fig. 4.7):

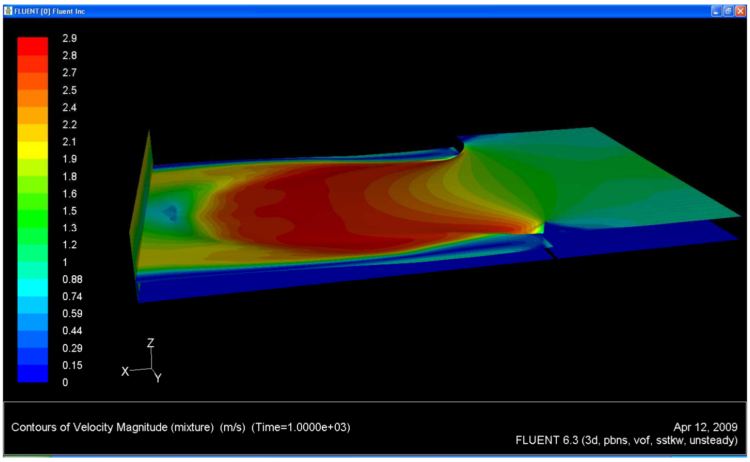

Fig. 4.6 Contour of velocities

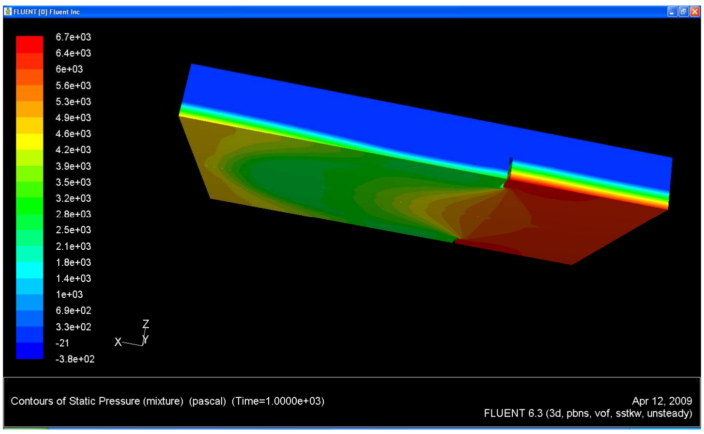

Fig. 4.7 Contour of pressure

We can represent the vectors of velocity in various sections (Fig. 4.8):

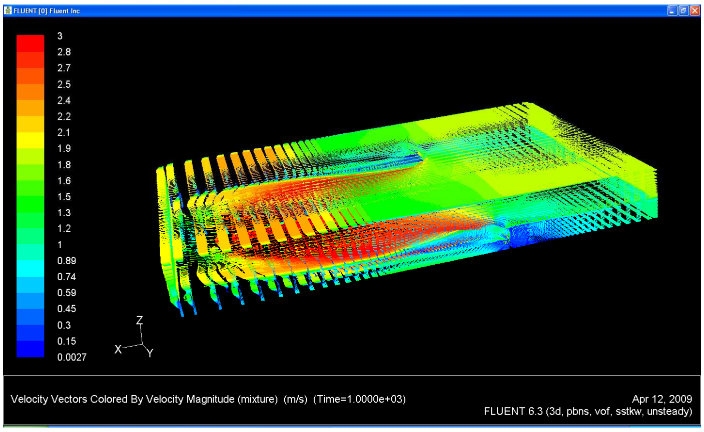

Fig. 4.8 Velocities in various sections of the field

The force acting on model brakewater is shown in table 4.1:

Force vector: (1 0 0)

zone name	pressure force n	viscous force n	total force n	pressure coefficient	viscous coefficient	total coefficient
barrage	**1714.27**	0.013	1714.283	1.1428	8.719774e-06	1.14285
net	1714.27	0.013	1714.283	1.1428	8.719774e-06	1.14285

Table 4.1

The entrance masic flow calculate in FLUENT ie presentated in the table 4.2:

	Mass Flow Rate (kg/s)
entrance	3620.84
Net	3620.84

Tabelul 4.2

5. THE BARRAGE IN THE NATURE

According to (2.4) the scale of the force is $k_F = k_l^3$.

So the force acting on the remaining brakewater is:

F = 1714 x 25^3 = 26 781 250 N = 2 678*10^3 daN.

After establishing the scale of time:

$$k_t = \frac{k_l}{k_v} = \frac{k_l}{\sqrt{k_l}} = \sqrt{k_l} = 5 \qquad (5.1)$$

the scale of masic flow can be computed with the formula($k_\rho = 1$, the same fluid on model and in the nature):

$$Q_m = \rho V / t \Rightarrow k_Q = k_l^3 / \sqrt{k_l} = k_l^{\frac{5}{2}} = 3125 \qquad (5.2)$$

So the entrance mass flow will be:

Q_m = 3620 x 3125 = 11 312 500 kg/s. (5.3)

We are discussing about great velocity - 10 m/s passing through a big section - 250 x 12,5 m.

6. CONCLUSIONS

As I specified before, it is difficult to achieve a model for experimenting. Also it is difficult to calculate the phenomena in the nature scale using the FLUENT. So we calculated the physical parameters, using FLUENT on the model and we pass them, using the similitude criteria, in the nature.

The results obtained using the single scale similitude method are very close to the nature. The main idea is that FLUENT can be used as an experimental stand.

As regards distortional similitude – two scale similitude, we will approach it in a future paper. Some problems, especially related to the long objects (conduit, brake waters, etc.) can be solved using two geometrical scales (one for length and one, smaller, for diameter). By applying the formulas for distortional similitude, we can pass from the model to the nature.

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