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CFD ANALYSIS OF LIQUID STREAM GOING THROUGH THE WIRE-SCREEN MESH

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ABSTRACT

Wire-screen mesh is normally used for the removal of particles from a liquid stream. Here we consider a system where fluid passes wire-screen mesh perpendicularly. The configurations of wire-screen mesh such as diameter and shape factor of wire affect the stream of fluid going through the screen. In this study, we performed a theoretical approach to the relation between wire mesh and fluid stream with computational fluid dynamics (CFD). FLUENT is used for the simulation. Head loss can be estimated by Rose equation when the stream passes through the wire-mesh (Rose 1945). The drag coefficient (C_D) varies with the stream types. The other parameters depend on a specific mesh, velocity and pressure. In the experiment we used a screen of 50 mesh-size and water as a fluid. The pressure drop during water flow was determined. The average and maximum velocities of water were calculated. On the basis of these values, we derived a proportional factor between the velocity of fluid and head loss that can estimate C_D.

INTRODUCTION

Screen-mesh is used to filter or capture particles of which size is bigger than the mesh size from a fluid containing a mixture of particles. Especially wastewater treatment process employs screen meshes with an aperture of 0.02~6 mm. The screen-mesh process operates in three different modes of static, drum and step. This can treat maximum 0.13 m^3/s waste water in the small-size sewage disposal plant [1]. However, the presence of screen-mesh generates the resistance against the fluid stream. A literature survey shows that there is no reliable theoretical or experimental basis for the estimation of the resistance or pressure drop in this type of system. In an industrial practice particles can be deposited on the surface of the screen-mesh with time and some mesh will be clogged with particles that will reduce flux and increase pressure drop.

A good estimate of flux and resistance by the mesh will make it possible to select screen type and the period of replacement with some confidence.

The approach we are going to take is the fluid mechanical characteristic of no-particle fluid stream through the wire mesh. Through this we will be able to assess the head loss and flux. In recent years, computational fluid dynamics (CFD) techniques have been used to study an analysis of fluid stream. The CFD makes it possible to calculate the velocity of fluid and head loss in one lattice of screen-mesh to analyze the characteristic of fluid stream through whole mesh area. We have done some experiment with U-tube to compare the results between the simulation and experimental filtration. The results have been applied to Rose equation so that we might confirm the relationship among pressure, velocity and drag coefficient (C_D) of the fluid throughout U-tube.

Whenever the filtration is performed, C_D makes it effective to choose the proper screen-mesh by estimating the head loss of fluid stream with a designed flux of a fluid.

NOMENCLATURE

C_D	[-]	Drag coefficient
C_D*	[s^2/m]	Drag coefficient including various constants
D	[m]	Wire diameter (width)
d	[m]	Wire diameter (depth)
g	[m/s^2]	Gravity
h_L	M	Head loss
V_a	m/s	Approach velocity
V	m/s	Velocity through the mesh
ε	[-]	Surface porosity
Φ	[-]	Shape factor

THEORY

When a fluid going through the porous media with uniform diameter. The head loss of this fluid can be expressed as Rose equation [2, 4].

$$h_L = \frac{1.067}{\phi}\frac{C_D}{g}D\frac{V_a^2}{\varepsilon^4}\frac{1}{d} \qquad (1)$$

Equation (1) represents the relationship between head loss and the magnitude of the closure of porous media. If the filter layer becomes closed, the valid porosity and the velocity decrease together. Thus, head loss occurs immediately.

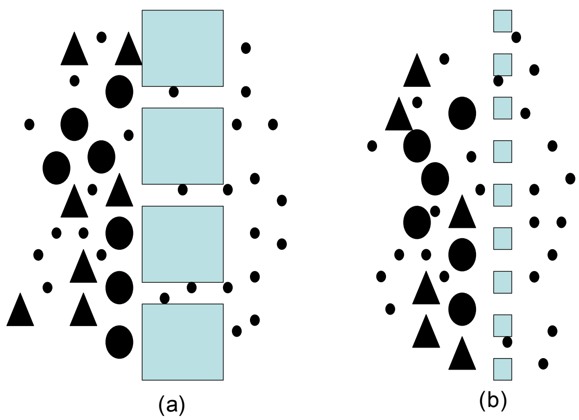


Figure 1. Schematic drawing of (a) a porous membrane and (b) wire-mesh (▲ , ■ : large particles, • :fluid)

As it is shown in Figure 1, it is possible to assume that they have similar pathway of fluid stream [3]. Therefore, we have applied the same equation to both normal screen-mesh and porous media which has uniform diameter.

$$h_L = C_D^* V_a^2 \qquad (2)$$

Equation (2) shows that C_D^* includes all the characteristic of experimental apparatus and other constants, and that the head loss is proportional to C_D* and V_a^2.

EXPERIMENTAL APPARATUS AND METHOD

We made the U-tube modeled after real pipe for waste water treatment. Water was used as a fluid.

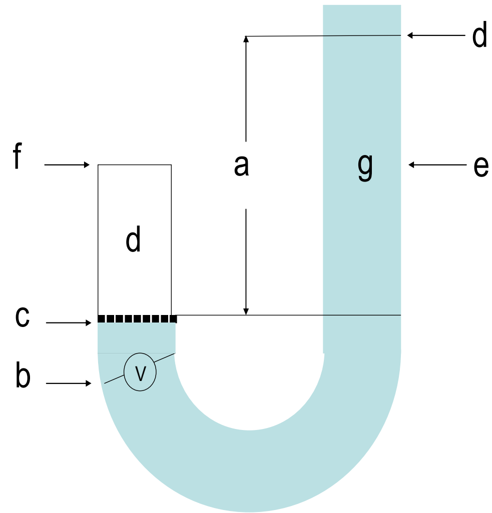


Figure 2. Diagram of U-tube

The U-tube was made of PVC (poly vinyl chloride). As represented Figure 2, on the left side of U-tube there are mesh (c) and valve (b) to control the passage of fluid. Tube (d) is made of apparent acryl material to detect the position of water stream. Diameter of tube was 11 cm. Mesh was composed with steal wire and 50-mesh (standard mesh size) was used.

In order to make up pressure, tube (g) was filled with water to position (d) with valve closed. Time was directly measured and it was confirmed at four positions (every 20 cm) while the altitude lowered from (d) to (e) position with valve opened. The fluid stream that went through the mesh arrived at (f) position from c. Since the ends of both tubes were open to the atmosphere, there were no effects of the atmospheric pressure.

SIMULATION RESULTS

For simulation, we used a commercial CFD program ‘FLUENT’. Figure 3 shows each inlet and outlet modeled after one lattice of 50-mesh used for experiment. The diameter of the wire was 203 ㎛ and the aperture of wire was 310 ㎛ (open area: 36%). Both lengths from inlet to mesh and from mesh to outlet were 2,500 ㎛, respectively. With the change of fluid head (75, 55, 35 and 15 cmH_2O), we calculated the velocity and head loss. To analyze the fluid characteristics of water stream, K-ε turbulence equation was used and we composed 3-dimensional mesh in the lattice model.

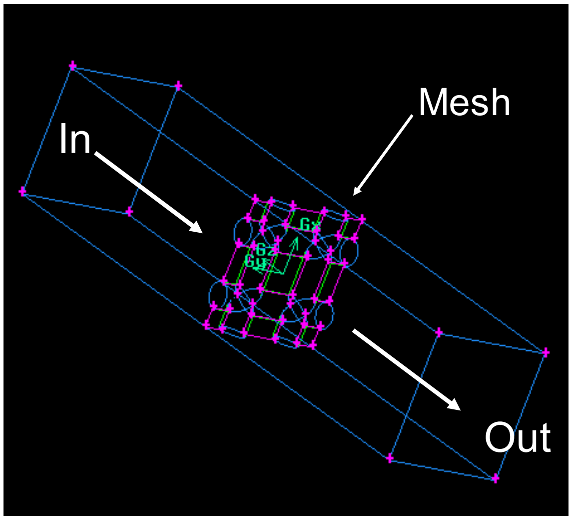
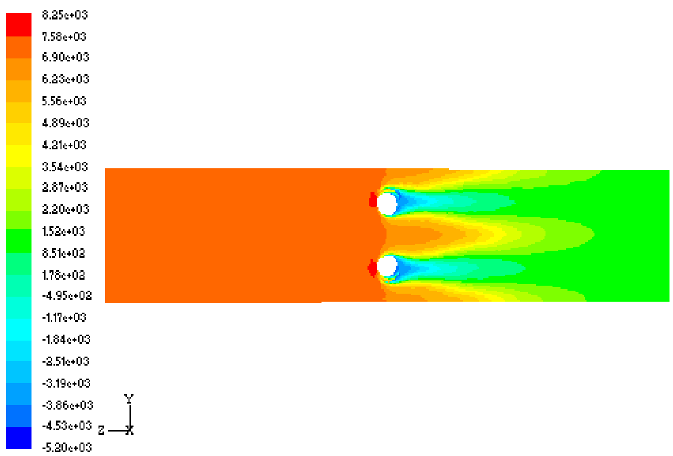
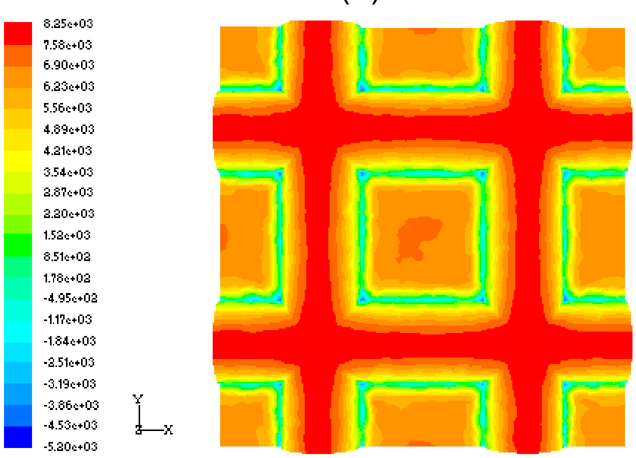


Figure 3. A lattice model of 50 Mesh wire screen

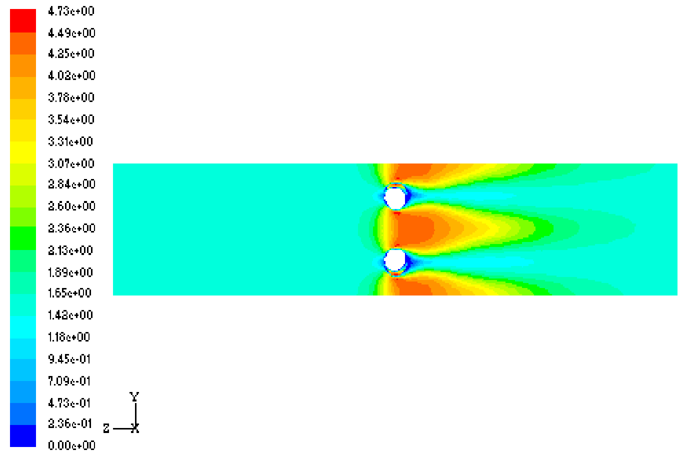
When the residual property of each parameter (continuity, X-velocity, Y-velocity, Z-velocity, k and epsilon) was below 10^{-3}, we determined that it reached the convergence. After 4,000 times repeated, the value of convergence was obtained. The results were shown in Figure 4 and Table 1.



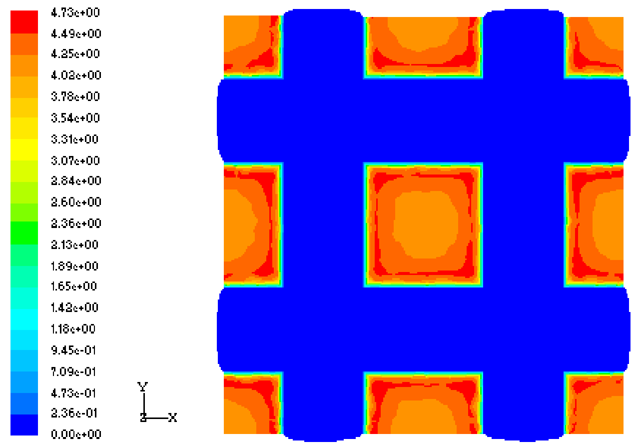
(a)



(b)



(c)



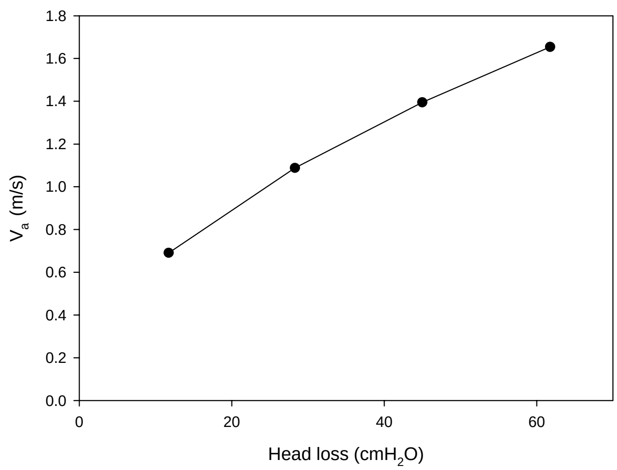
(d)

Figure 4. Flow pattern of lattice (a) Pressure profile (side view) (b) Pressure profile on the side of mesh (c) Velocity profile (side view) (d) Velocity profile on the side of mesh

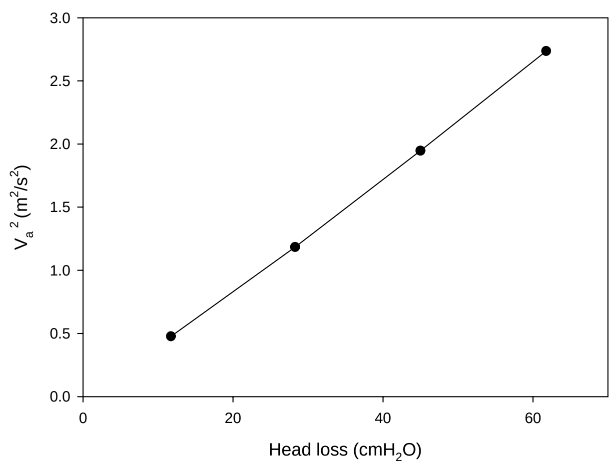
Table 1. Results of simulation

Inlet Pressure (Pa)	Outlet Pressure (Pa)	Head Loss (cmH_2O)	V_a (m/s)	V (m/s)
7,577	1,523	61.78	1.654	4.253
5,522	1,112	45.00	1.395	3.587
3,490	718	28.29	1.088	2.798
1,475	326	11.72	0.691	1.777

Depending on these results, we could confirm head loss through the pressure drop between the inlet and outlet. And then, it was possible to draw a graph related to these values and approach velocity (V_a).



(a)



(b)

Figure 5. Relations between head loss and Velocity (a) : V_a, (b): V_a^2

Figure 5 shows that the fluid head loss (x-axis) is not linearly related to the y-axis in (a) while a direct proportional relation is shown between head loss and the square of the approach velocity (b). This is consistent with the Rose equation shown in equation (2).

EXPERIMENTAL RESULTS

An experiment was carried out in a U-tube device shown in Figure 2. Water was filled up to a height of 150, 110, 70 and 30 cm, then, the valve (b) in Figure 2 was opened instantaneously and the time for the water level in the right side of the tube to reach a given position was measured. In order to determine the velocity at the mesh, the average approach velocity was multiplied by area of tube and this is called a flux. And then, it was divided by the area of mesh and porosity that gives V. Then the head loss shown in Table 2 was estimated with the contraction ($V_a \rightarrow V$) and expansion ($V \rightarrow V_a$) head loss by the mesh [5].

Table 2. Results of experiment

V_a (m/s)	V (m/s)	Head Loss (expansion, cmH_2O)	Head Loss (contraction, cmH_2O)	Head Loss (total, cmH_2O)
1.607	4.467	42.73	4.665	47.30
0.8030	2.232	10.41	1.164	11.57
0.5446	1.513	4.784	0.5357	5.320
0.4461	1.24	3.216	0.3694	3.585

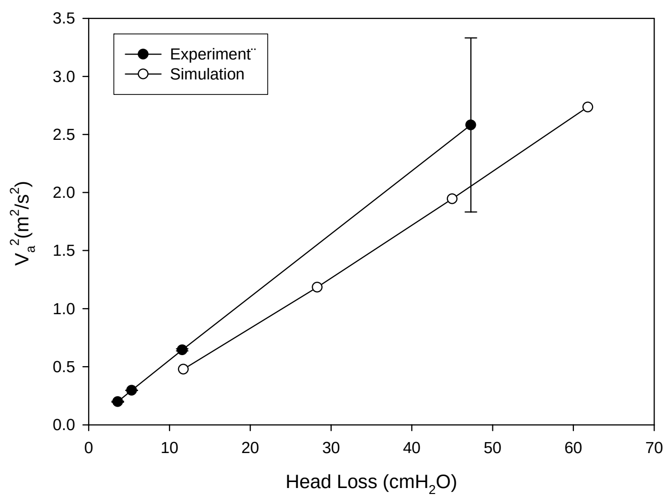


Figure 6. Experimental and simulated value of fluid velocity

Figure 6 compares the simulation head loss and the experimental head loss. These two data fits relatively well considering the accuracy of the experiment at a high approach velocity of 1.607m/s. In this case the fluid speed was so high that a short stop-watch time measurement does not have much reliability (the first data-•). Also, the Reynolds number (Re) was calculated to be in the range of 300~1400 in this particular case that are not in the laminar flow regime. The other three experimental data points are very accurate.

DISCUSSION

Wire mesh tray is commonly used in separating various sizes of solid particles in a liquid. Microfiltration uses membranes with pore sizes as small as 0.1 μ m and thickness of about 20 μ m. The aspect ratio of membrane thickness/pore size amounts to around 200. In contrast, wire mesh filtration system may have a wire mesh as large as 2.5cm. But my application of removing solid particles from a liquid stream needed wire meshes as small as 10~20 μ m. Separation of particles using such a small wire mesh is important, but more important work is to estimate flux with such a mesh using even pure water. This CFD work shows that the CFD analysis will be useful in estimating pure water flux in a wire mesh that has a very small aspect ratio in comparison with microfiltration membrane with a very high aspect ratio.

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