Computer-Aided Project of Numerical Heat Transfer

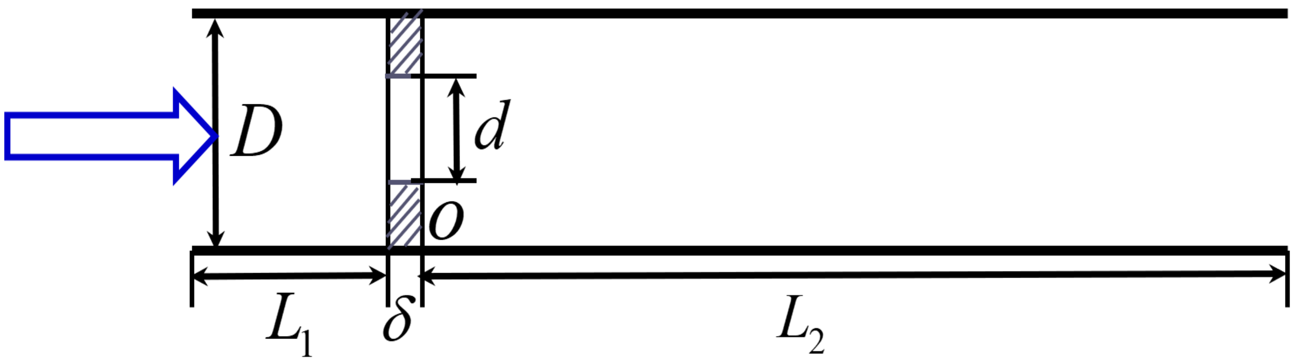
Xi’an Jiaotong University

In this year we present three computer-aided projects: one is to be solved by our teaching code, the other two are to be solved by FLUENT. Every student can choose one project according to your interest and condition.

For the first project the self-developed computer code should attached in your final report.

For the second and third projects you should indicate your choices when using FLUENT.

Project 1----for students who uses teaching code



Flow stream with fully developed velocity distribution and room temperature goes into a tube with a orifice as shown in the figure. Flow is laminar and incompressible.

Given:

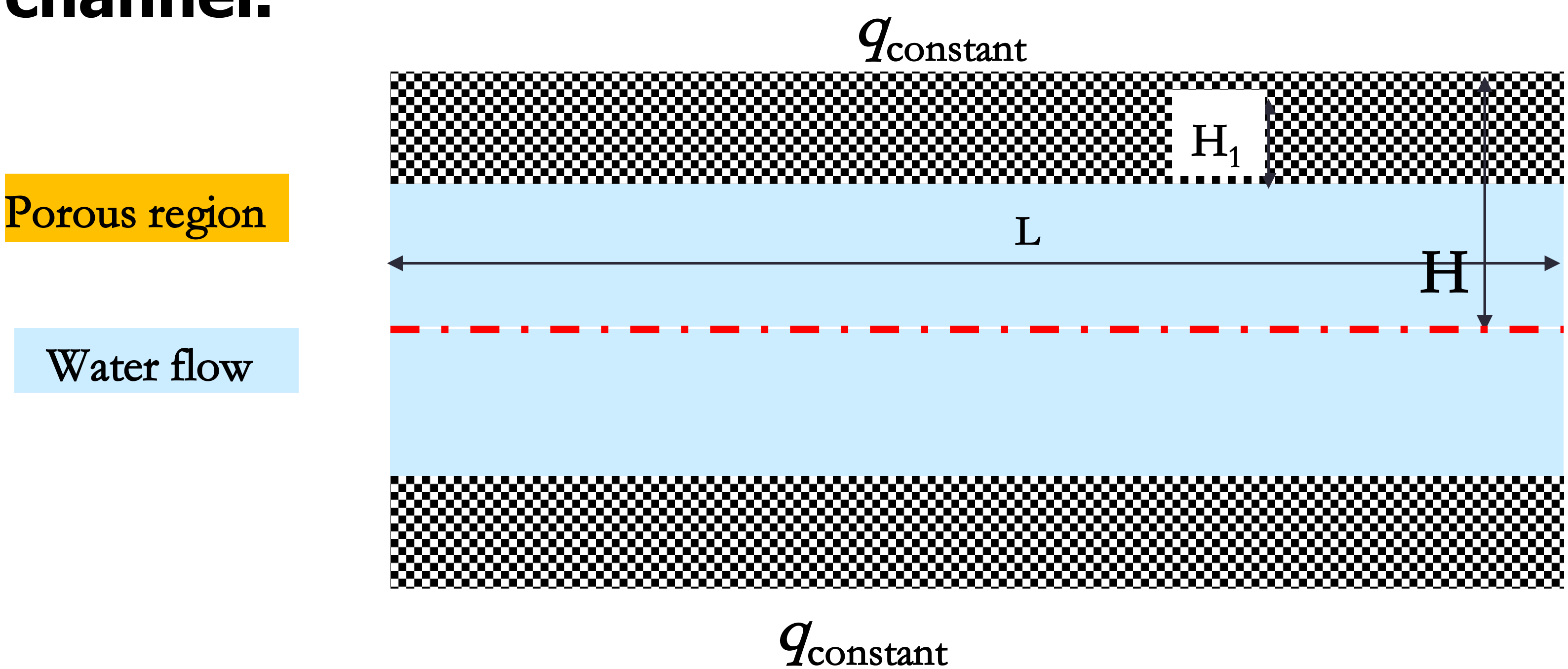
$$\frac{d}{D}=0.4 \textbf{ to } 0.6; \quad \frac{L_1}{D}=1; \quad \frac{\delta}{d}=0.5$$

$\frac{L_2}{D}$ may take any appropriate value.

Find: **Adopt three Reynolds number and one ratio of *d/D*, find the positions of the reattachment point, L_r / D ,where L_r is counted from point O shown in the figure.**

Project 2----for students who uses Fluent software

Known： Porous medium is partially inserted into an 2D channel to enhance the heat transfer. The fluid is water and the porous region is aluminum metal foam. The porous region is attached to the outer wall of the channel.



Computational domain

Parameter	H	L	ρ_{water}	η_{water}	$c_{p\ water}$	λ_{water}	ε
Value (Unit)	0.06 (m)	3 (m)	998.2 ($kg\cdot m^{-3}$)	998×10^{-6} ($kg\cdot m^{-1}\cdot s^{-1}$)	4182 ($J\cdot kg^{-1}\cdot K^{-1}$)	0.597 ($W\cdot m^{-1}\cdot K^{-1}$)	0.9

Assumptions:

constant physical properties, steady, laminar flow

Boundary conditions

Boundary	Condition
x=0	$v_x=U_{in}$, T=300 K
x=L	p=0 Pa , $T_{backflow}$=300 K
$y=0$	symmetry
y=H	$v_x=v_y=0$ $q=500 Wm^{-2}$
Porous region	Thermal-equilibrium model

Solve:

$$PN = \frac{Nu / Nu_{\text{base case}}}{\Delta p / \Delta p_{\text{base case}}}$$

Simulate the heat transfer and laminar flow based on above conditions. Analyze the *Nu*, pressure drop (ΔP) and PN at different *Re* and permeabilities (every one in the same group will run totally 16 cases). Thermal-equilibrium model is adopted for porous medium region. KC equation is adopted to calculate the permeability.

$$Re = \frac{\rho u_{\text{inlet}} \text{H}}{\mu} \qquad k = \frac{D_{\text{p}}{}^2 \varepsilon^3}{150(1-\varepsilon)^2}$$

The homework is divided into 5 groups based on different tail numbers of student ID.

Tail numbers of student ID: 1, 6

Group 1	Thickness of porous region H_1
	0.02 (m)

D_p \ Re	Re=100	Re=200	Re=300	Re=400
0.0025	0.0025	0.0025	0.0025	0.0025
0.00079	0.00079	0.00079	0.00079	0.00079
0.00025	0.00025	0.00025	0.00025	0.00025
0.000079	0.000079	0.000079	0.000079	0.000079

Base case

D_p is the diameter of particles

Tail numbers of student ID: 2, 7

Group 2	Thickness of porous region H_1
	0.03 (m)

Re / D_p	Re=100	Re=200	Re=300	Re=400
0.0025	0.0025	0.0025	0.0025	0.0025
0.00079	0.00079	0.00079	0.00079	0.00079
0.00025	0.00025	0.00025	0.00025	0.00025
0.000079	0.000079	0.000079	0.000079	0.000079

Base case

D_p is the diameter of particles

Tail numbers of student ID: 3, 8

Group 3	Thickness of porous region H_1
	0.04 (m)

D_p \ Re	Re=100	Re=200	Re=300	Re=400
0.0025	0.0025	0.0025	0.0025	0.0025
0.00079	0.00079	0.00079	0.00079	0.00079
0.00025	0.00025	0.00025	0.00025	0.00025
0.000079	0.000079	0.000079	0.000079	0.000079

Base case

D_p is the diameter of particles

Tail numbers of student ID: 4, 9

Group 4	Thickness of porous region H_1
	0.05 (m)

Re / D_p	Re=100	Re=200	Re=300	Re=400
0.0025	0.0025	0.0025	0.0025	0.0025
0.00079	0.00079	0.00079	0.00079	0.00079
0.00025	0.00025	0.00025	0.00025	0.00025
0.000079	0.000079	0.000079	0.000079	0.000079

Base case

D_p is the diameter of particles

Tail numbers of student ID: 5, 0

Group 5	Thickness of porous region H_1
	0.055 (m)

D_p \ Re	Re=100	Re=200	Re=300	Re=400
0.0025	0.0025	0.0025	0.0025	0.0025
0.00079	0.00079	0.00079	0.00079	0.00079
0.00025	0.00025	0.00025	0.00025	0.00025
0.000079	0.000079	0.000079	0.000079	0.000079

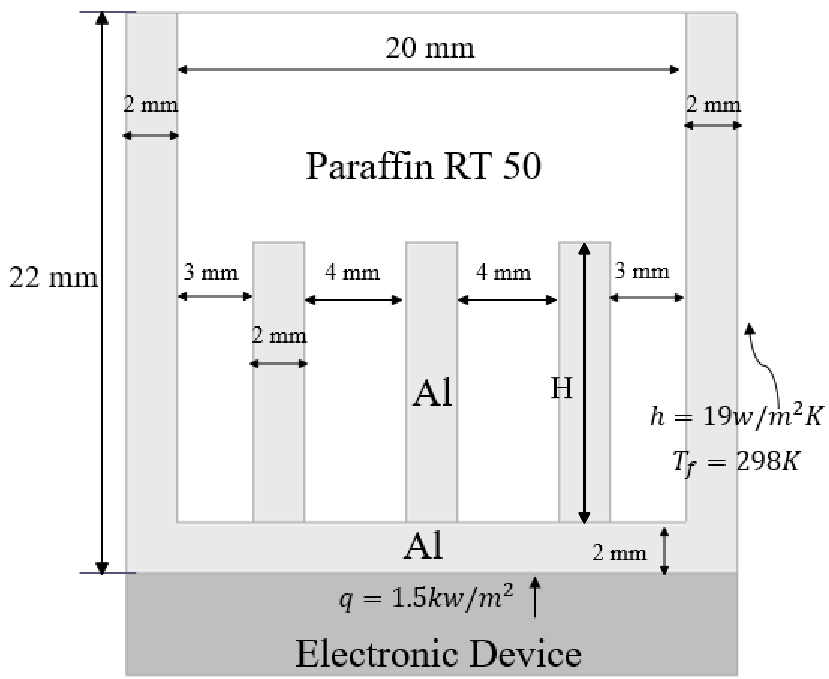
Base case

D_p is the diameter of particles

Project 3----for students who uses Fluent software

Background： Thermal management is essential for modern electronic devices to keep their normal working functions. Due to its high latent heat and nearly constant temperature during solid-liquid phase change, inserting phase change material (PCM) is an effective approach to control the thermal performance of electronic facilities. However, the low PCM thermal conductivity impedes its heat transfer capability so that extended fins are usually used to enhance the heat transfer rate.

Known: The computational domain is shown in the figure. The square cavity is initially filled with solid Paraffin RT 50. The fins (shown in grey region) are made of Aluminum. The square cavity and aluminum fin configurations are shown in the Figure. The initial temperature is $T_i = 298\,K$.



Boundary condition: **The heat flux of 1.5 kW/m² is input from the bottom of the square cavity, and the other three surfaces are cooled by the air with a heat transfer coefficient of h=19 W/(m²·K) and air temperature of T_f=298 K. The conjugate heat transfer occurs between Paraffin and Aluminum fins. The thermophysical properties of Paraffin RT 50 and Aluminum are constant which are presented in the Table.**

Material	ρ(kg/m^3)	k (w/m·K)	μ (Pa·s)	Cp (J/kg·K)	β (1/K)	ΔH(J/kg)
Paraffin RT50	780	0.2	0.000365	2000	0.0003085	255000
Aluminum	2719	202.4	-	871		-

Find： Write down the governing equations and boundary conditions; Nondimensionalizing all the equations to get dimensionless governing parameters. Find the transient temperature, streamlines, and solid-liquid interface evolutions. Find the maximum temperature in the computational domain versus time.

Note： The natural convection is driven by the buoyancy force with Boussinesq approximation. ρ is the density; k is thermal conductivity; μ is dynamic viscosity; C_p is specific heat; β is thermal expansion coefficient; ΔH is the latent heat of Paraffin; The Electronic Device region is not required to be included inside the computational domain!

The fin height *H* is different according to your student ID as shown below.

For the tail number of student ID:0, 5

The fin height H is 10 mm.

For the tail number of student ID:1, 6

The fin height H is 11 mm.

For the tail number of student ID:2, 7

The fin height H is 12 mm.

For the tail number of student ID:3, 8

The fin height H is 13 mm.

For the tail number of student ID:4, 9

The fin height H is 14 mm.

Suggestions and Requirements

1） The solution should be grid-independent.

2） The project report should be written in the format of the Journal of Xi'an Jiaotong University. Both Chinese and English can be accepted.

3） When the teaching code is adopted, please submit in the USER part developed by yourself for solving the problem.

4） When FLUENT is adopted, please indicate the chooices you made to implement the simulation.

The project report should be due in before April 30, 2019 to room 204 of East 3rd Building.

感谢各位同学

Happy New Year

同舟共济渡彼岸!

People in the same boat help each other to cross to the other bank, where….