國立清華大學命題紙

99學年度 化學工程學系 碩士班入學考試 *請在【答案卷卡】作答

科目 輸送現象及單元操作 科目代碼 0701 共 5 頁，第 1 頁

1. Mr. Lin was requested to design an extrusion die to deliver a thin liquid mixture sheet. He first examined the viscosity data of this material at two different temperatures. The viscosity data as a function of shear rates are given in Figure A (see Page 3).

(a) What are the SI units of viscosity m and shear rate S?(2%)

(b) Mr. Lin was confused with the data at high shear rates where the two sets of data are overlapping. He was confirmed that the measurements were reliable, can you offer a reasonable physical explanation to this overlapping phenomenon?(2%)

(c) To play safe, Mr. Lin decided to design an experimental die based on the data at low shear rates, or Region I in Figure A. He first took a macroscopic approach to design a simple die as shown in Figure B (see Page 3), he assumed only the viscous effect of the liquid is important, the operation should be isothermal, steady-state, flows in both the circular channel and slot section as shown in Figure B are assumed to be one-dimensional and fully developed (or at least locally fully developed). He assumed that the pressure gradient in the Z-direction in the slot section is constant, but the pressure gradient in the circular channel is a function of X -direction only, then he could find two pressure drop/flow rate equations in the circular channel and the slot section separately as shown below:

$$Q = F(-dP/dX, m, A1, A2, \ldots) \qquad (1)$$

$$q = G(P/Le, m, A1, A2, \ldots) \qquad (2)$$

Here Q is the volumetric flow rate in the circular channel; q is the volumetric flow rate per unit die width at the exit of the slot section. P is pressure in the circular channel. Ai, i = 1, 2,…, are geometric parameters of the die as shown in Figure B. Can you derive these two equations F and G? (4%)

There are three unknowns Q, q and P is the two equations, so one more equation is needed, which is as follows:

$$dQ/dX = -q \qquad (3)$$

Physically, this is a material balance equation, which implies the loss of liquid in the circular channel is equal to the amount that enters the slot section.

The three equations can be recombined to eliminate q and P and with Q as the only remaining unknown variable, the resulting equation is a second-order ODE, please derive this equation (4%).

(d) This equation can be solved with the following two boundary conditions:

$X = 0$, $Q = Qo$.(here Qo is a known inlet flow rate) (4a)

$X = L$, $Q = 0$. (4b)

Can you obtain an analytical solution of this equation (3%)?

Can you derive the dimensionless form of the equation? (3%)

(e) Once Q is known, can you figure out how to deliver the liquid sheet with acceptable lateral uniformity? That means q should be almost the same at the exit of slot section along the X- direction. (2%)

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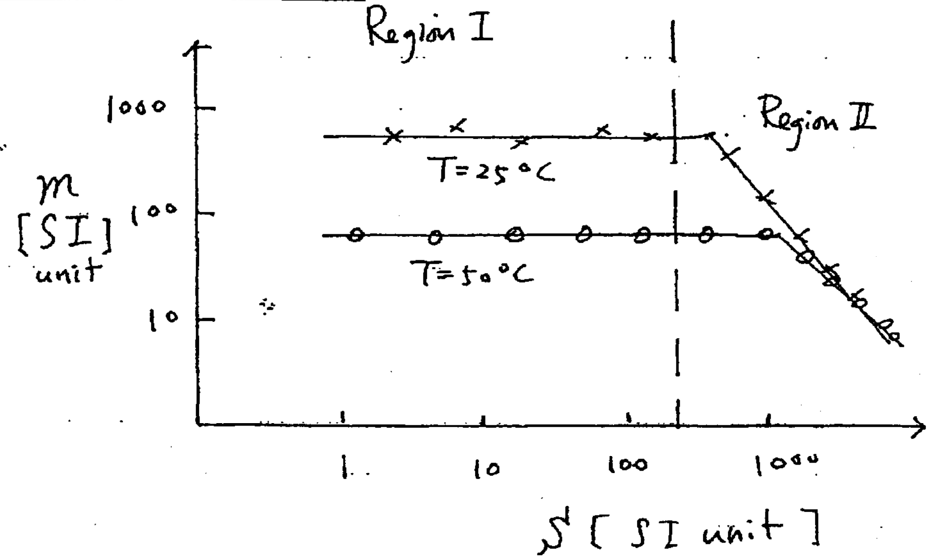

Figure A

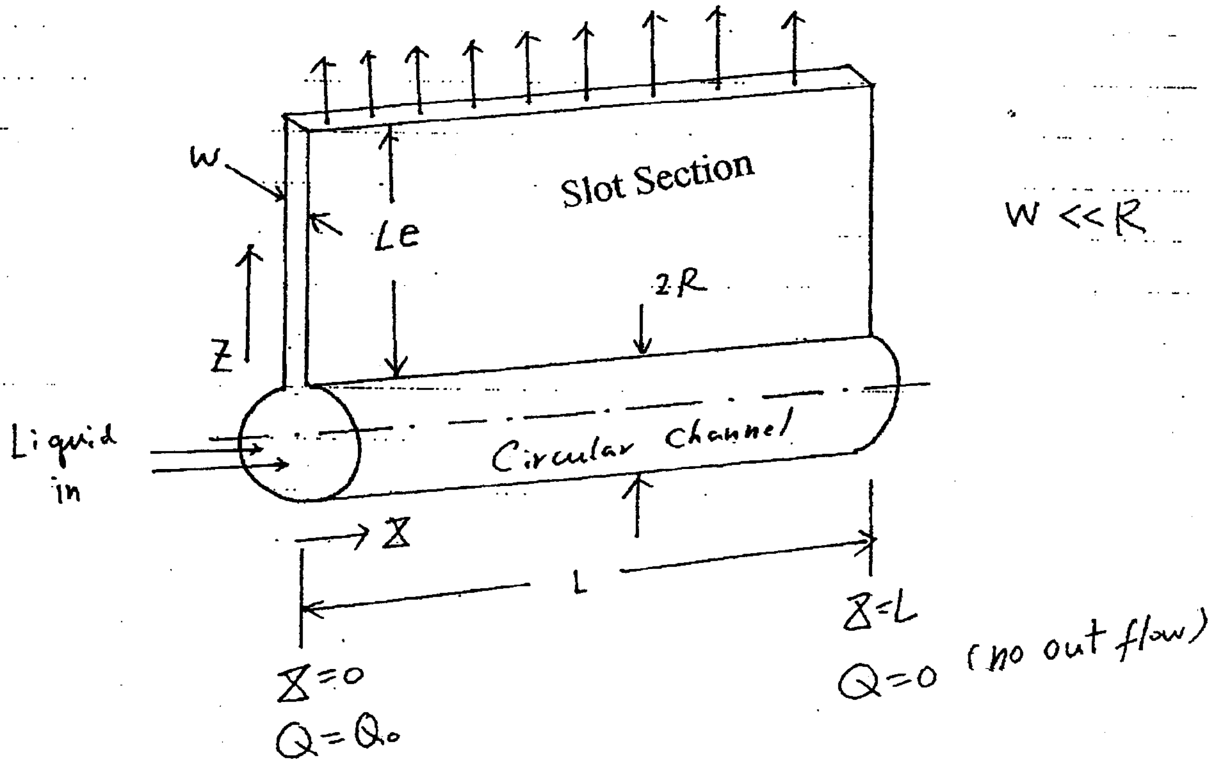

Figure B

2.(a) Answer the following questions relating to energy transport.

(i) Define and give the dimensions of heat transfer coefficient h, thermal diffusivity α, and heat flux **q**. For the dimensions use m = mass, l = length, T = temperature and t = time. (3%)

(ii) In what way are Newton's law of viscosity and Fourier's law of heat conduction similar ? Dissimilar ? (3%)

(iii) The dimensionless group X links the thermal boundary layer thickness δ_t with the momentum boundary thickness δ. What is X? What is the physical meaning of $X = 1$? (4%)

(b) Two large flat porous horizontal plates are separated by a relatively small distance L. The upper plate at $y = L$ is at temperature T_L, and the lower one at $y = 0$ is to be maintained at a lower temperature T_0. To reduce the amount of heat that must be removed from the lower plate, an ideal gas at T_0 is blown upward through both plates at a steady rate v_y. Develop an expression for the temperature distribution and the amount of heat q_0 that must be removed from the cold plate per unit area as a function of the fluid properties and gas flow rate. (10%)

3. Gas A is absorbed by a stationary liquid solvent S, the latter containing solute B. Species A reacts with B in an instantaneous irreversible reaction according to the equation $aA+bB \rightarrow$ products. It may be assumed that Fick's second law adequately describes the diffusion processes and the diffusions can be taken as binary diffusions, since A, B, and the reaction products are present in S at low concentrations. Because of the instantaneous reaction of A and B, there will be a plane parallel to the liquid-vapor interface at a distance z_R from it, which separates the region containing no A from that containing no B. Further assume that the depth of the liquid solvent is much larger than the possible diffusion length of A. Let C_{A0} be the concentration of A at the liquid-vapor interface, C_{B0} be the starting concentration of B, and D_{AS} and D_{BS} be the diffusivities of A and B in S, respectively.

(a) Give the governing equations for concentration of A, C_A, and concentration of B, C_B. You should specify the domains where the governing equations apply. (4%)

(b) Give the suitable initial and boundary conditions for C_A and C_B. Note that there are one initial condition and 5 boundary conditions. Please also give the corresponding physical meaning of these conditions. (12%)

(c) Is z_R a function of t? Why? (2%)

(d) Will the molar flux of A at the liquid-vapor interface increase or decrease with t? Why? (2%)

4.

(a) Explain the mechanism of thermal conduction for gases. Why dose hydrogen (0.167 W/m·K at 273 K) have a higher thermal conductivity than air (0.0242 W/m·K at 273 K)? (5%)

(b) Explain the mechanism of thermal conduction for solids. Why dose ice (2.25 W/m·K at 273 K) have a thermal conductivity greater than water (0.569 W/m·K at 273 K)? (5%)

(c) A heavy hydrocarbon oil which has a c_{pm} = 2.30 kJ/kg·K is being cooled in a heat exchanger from 371.9 K to 349.7 K and flows inside the tube at a rate of 3630 kg/h. A flow of 1450 kg water/h enters at 288.6 K for cooling and flows outside the tube. Calculate the water outlet temperature and heat-transfer area if the overall U_i = 340 W/m^2·K and the streams are countercurrent. Assume a c_{pm} = 4.187 kJ/kg·K for water. (10%)

5.

(a) Please answer the following questions on distillation. (10%)

(i) Describe how reflux ratio influences the separation result of a distillation operation.

(ii) Explain the meaning of a total condenser.

(iii) Compare the performance of sieve trays and valve trays.

(iv) Is it possible to get 99% mol of ethanol from distillation of dilute ethanol/water solution? Why? Suggest ways to do it.

(b) An antibiotic A is to be extracted from water to solvent at pH 2.5, where partition coefficient K_D ($=C_{A,\,solvent}/C_{A,\,water}$)= 50. If the solvent flow rate is set at 0.35 times the water rate, how much of A in the feed can be recovered if the extractor is equivalent to 1 ideal stage? Assume the solutions involved are all dilute enough that the partition coefficient is constant throughout the process, and the solvent and water are totally immiscible. (10%)