tentamen ta3220: Fluid flow, heat and mass transfer

9.00-12.00 uur, 23 June 2006, TA Gebouw

This is an open-book exam. There are 4 questions in 2 pages, with a total mark of 60. Please read each question well, before you prepare the answers.

Question 1 - pressure gradient in a pipe and in an annulus *(20 marks)*

Light oil is flowing through a straight, smooth, horizontal pipe at room temperature. The diameter of the pipe is 5.0 cm. Later on this oil is led from the pipe to an annulus. This annulus is also smooth, straight and horizontal; in addition it is concentric. The annulus inner and outer diameters are 7.0 cm and 8.5 cm, respectively. The flow rate through pipe and annulus is 2.80 m^3/h.

Questions:

(1) Calculate the pressure gradient in the pipe (in Pa/m).

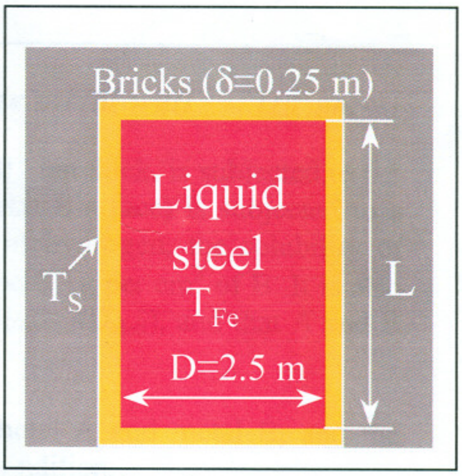
(2) Calculate the pressure gradient in the annulus (in Pa/m).

Other data:

- Specific mass of the oil: 800 kg/m^3.
- Dynamic viscosity of the oil: 0.0035 Pa.s.

In case it is necessary to calculate a friction factor for turbulent pipe flow, use the relation of Blasius: $f = 0.0791\ Re^{-1/4}$. Furthermore it is noted that the hydraulic diameter, necessary to calculate the Reynolds number for flow in a channel with a non-circular cross-section, is 4*(area)/(total circumference).

Question 2 -Temperature drop of liquid steel in a ladle *(15 marks)*



Liquid steel at 1650°C is rapidly poured to a refining ladle to a depth of 2.5 m, and the cylindrical ladle is 3 m in outer diameter and with a refractory lining of 0.25 m thick. The ladle was preheated to 700°C before filling the steel, and after filling the ladle is quickly covered with a well-insulated lid.

Please calculate:

The temperature drop of the liquid steel after 10 minutes standing time before refining operation starts?

Assumptions:

(1) Ladle outer surface temperature can be regarded as constant during the first 10 minutes after filling the liquid steel.

(2) The ladle inner surface temperature after liquid steel filling reaches the same temperature of liquid steel, and the temperature gradient of within the liquid steel is negligible.

(3) The heat loss from the top and bottom of the ladle is small, and can be neglected.

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Property data (for question 2):

Liquid steel:	density = 7050 kg/m^3, heat capacity = 750 J/kg.K
Ladle refractory:	thermal conductivity = 2.0 W/m.K

Question 3 - Heating of liquid metal in a pipe ***(15 marks)***

Molten aluminum at 700°C is to be heated while being transferred from a melting furnace to a casting tundish by pumping it through a heated tube of 50 mm in inner diameter, at a flow rate of 1.3 kg/s. The tube wall is kept at a constant temperature of 780°C.

Questions:

(1) Estimate the average heat transfer coefficient between the wall and the liquid aluminum. Assuming the total length of the tube is greater than 60 times of the diameter.

(2) Using the above calculated value of heat transfer coefficient, how long would the tube have to be, to heat the aluminum from 700 to 750°C? Conduction in the direction of flow could be neglected.

The data for liquid aluminum at temperatures between 700 and 780°C:

Thermal conductivity:	k=86 W/mK
Density:	ρ=2560 kg/m^3
Specific heat:	C_p=1050 J/kgK
Dynamic viscosity:	μ=1.2×10^{-3} Pa.s

Question 4 - Hydrogen diffusion through a composite metal wall ***(10 marks)***

A composite foil made of metal A bonded to metal B, each 0.01 cm thick, is subjected to 0.5 atm of pure hydrogen on metal A's face. The other side (metal B's face) is subjected to a perfect vacuum). At the temperature of interest and 1 atm of hydrogen, the solubility of hydrogen in metal A is 4×10^{-4} g per cm^3 of A and in B it is 1×10^{-4} g per cm^3 of B. It is also known that hydrogen diffuses 4 times as fast in A as in B ($D_{H\text{-}A} = 4D_{H\text{-}B}$), and that A and B do not diffuse in each other.

Please calculate the surface concentration of hydrogen on metal A and metal B, and the interface concentrations between A and B, under steady-state condition.

(End)