Project: HZ3-1

Double Pipe Heat Exchanger

For the double pipe heat exchanger in the laboratory you are to determine its dynamic behavior. To determine the dynamic behavior you are to determine the time constant assuming an exponential decay for both heat-up and for cool-down under flow conditions. This can be done by initially starting the flow of cold water into the shell side of the heat exchanger and establishing a steady-state temperature reading without any steam flowing into the unit. Then turn on the steam. Wait until a new steady state temperature is obtained. The exponential rise of temperature for the cold water flow can then be analyzed for a time constant, t_c, which is the heat-up time constant. The cool-down time constant can be determined by starting at the end of the exponential rise of the cold water flow – this is steady state- and then shutting off the stream supplied to the system and watching the temperature of the cold water in the shell cool down to another steady-state. The best fit of the exponential cooling can again be characterized with a charactistic cool-down time. Using dynamic analysis, predict from first principles what the heat-up and cool-down times are for this apparatus and compare those predicted to those measured in your experiments.

Project: HZ3-2

Distillation Column

The bubble cap distillation unit must be tested and compared to McCabe-Thiele theory of operation. To do this the column must be operated at a constant reflux ratio with product streams being continuously taken from the top and bottom of the unit. Develop a system to continuously remove fluid from the reboiler while making sure that the liquid level in the reboiler keeps the heating coils wet with fluid. Run the apparatus at steady-state at 1.3 time minimum reflux ratio and determine the top and bottom composition to test the theory. During this run take samples from all try locations to determine the stage efficiencies. In your final report, make a direct comparison between the McCabe-Thiele theory predictions with the individual stage efficiencies accounted for and your experimental results. You can use a feed which is 25 vol% IPA in water for your test run.

Project: HZ3-3

Bioreactor

A biomedical company is producing a cancer drug from a genetically modified yeast strain in a conventional bioreactor and wants us to obtain more information on the growth kinetics of this organism using a similar bioreactor. The growth characteristics of this particular strain are identical to the common variety of yeast available in supermarkets. The organism to be used is ***Saccharomyces cerevisiae***, a yeast cell, and the growth medium should be composed of 10 g/l yeast extract, and 20 g/l bacto peptone in water. Additionally a sugar should be added. Typically we use 30 g/l glucose, but the company would also like to investigate the use of sucrose. Please compare runs of the bioreactor with an appropriately comparable concentration of sucrose.

The growth medium should be autoclaved for 15 minutes using our autoclave unit. The amount of yeast cells at the start of each reactor run can be varied, but normally we use 2.0 g/L. Typically, the reactor is operated at 37 °C, agitation rate of 500 rpm and the pH is maintained at 6.5. Since there is a limited amount of time for this lab, the bioreactor will be filled and the yeast inoculum will be added several hours before normal lab period. We will have to coordinate to assure you are able to get appropriate data in the afternoon. Your lab instructor and Bob Cox will explain how to operate the bioreactor and associated software.

Some of the kinetic parameters for cell growth that are being requested are (1) the specific glucose (or sucrose) uptake rate, and the cell yield coefficient based on a batch unsteady state experiment. Assume a Monod expression for the specific growth rate with glucose as the limiting reactant. Then determine one of the kinetic parameters in that expression, μ_{max} , by running several batch experiment(s). The objective of this assignment is to determine the kinetic parameters using the two different sugars and determine which is best for growing yeast and quantify the difference.

Project: HZ3-4

Heat Conduction

Monitor the transient heat conduction in the rods given an inlet of hot fluid at one end of the rod. Compare the experimental temperature to that predicted for the temperature transient at various distances down the rod. As part of your laboratory preliminary conference, develop the equations you will be required to use to predict the temperature transient profile for an aluminum rod as a function of location from one end where the temperature is held constant by condensing steam to the other. For your final report, you should do this prediction assuming 1) that the rod was one dimensional (length) and 2) that the rod was two dimensional (length and diameter). In this latter simulation, Comsol is suggested as the software of choice.

Project: HZ3-5

Liquid Flow Bench

Our local water treatment plant is interested in reducing their pumping costs for transporting their streams through packed media. They have a choice of three packing options: 1. A 1.25 meter bed of marble-sized packing; 2. A 0.70 meter bed of ceramic packing; or 3. A 0.10 meter bed of sand packing. As luck would have it, we have three packed beds in our liquid flow bench with the equivalent packing materials.

Your task is to determine the pressure drop across each bed as a function of flow rate, and compare your results to appropriate theory regarding the fluid dynamics within packed beds. As these columns have not seen flow through them in some while, please repeat several of your early measurements towards the end of your project to assure systematic error was not introduced through fowling (or the removal thereof by use).

In your report please recommend which packed bed option our client should use if pressure drop is their primary concern. Also, because there are other benefits and drawbacks to each packing material, please report on the bed thickness for Option 1 and 3 needed to obtain the same pressure drop found with Option 1 with the fluid flow rate at the maximum possible with our system.

Project: HZ3-6

Fluidized bed

Fluid bed reactors are used for many applications in industry from pulverized coal burning to catalytic crackers to silicon purification. Since there is excellent heat transfer in the fluid bed, coils are often inserted to heat or cool the bed allowing the reaction heat to be dissipated in exothermic reactions. Heat transfer and fluidization characteristics are different for different powders. A client has several powders (carbon, sand and glass beads) that need to be tested for their fluidization characteristics. The most important fluidization characteristic is that of the minimization fluidization velocity; the velocity of the gas just necessary to fluidize the powder. Please measure the minimization fluidization velocity for the client's powders. Compare the minimization fluidization velocities to a correlation in Leva, ("Fluidization " p. 63 McGraw-Hill, NY 1959). To make this comparison the particles in the powder must be characterized with respect to their density, particle diameter, and shape factor. In addition, determine the bed expansion as a function of the pressure drop and compare these results for the various powders to those calculated using the correlation in Leva, Chapt 4.

Using the fluidization results for the client's carbon sample design a fluid bed combustor for the reaction

$C + O_2 \rightarrow CO_2$

with the surface reaction rate given by Parker and Hottel (Ind. Eng. Chem. 28,1334,(1936))

$$\text{Rate}= -\frac{1}{4\pi R^2}\frac{dN_{O_2}}{dt} = 4.32x10^{11}\frac{cm}{s\sqrt{K}}\sqrt{T}e^{-44\frac{kcal}{mole}/RT}C_{O_2}\left(\frac{mole}{L}\right),$$

for 1 tonne/hr carbon combustion rate operating at 10% excess air at 1300K. Please note that you should also consider the rate of boundary layer diffusion as well as the surface reaction rate in the kinetic model used for design of the fluid bed combustor

Project: HZ3-7

Ebulliometer

You are interested in validating different Vapor-Liquid-Equilibrium (VLE) thermal models in Aspen for Methanol-Ethanol-Water mixture. For this project, you will first calculate the VLE with several thermal models in Apsen for Methanol-Ethanol-Water mixture. Compare the result from Aspen with the experimental data from the ebulliometer. Discuss the different thermal models in Aspen and the differences from the experimental data.