UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualification:-

M.Sc.

M11: Fluid Particle Systems

COURSE CODE : **CENG0M11**

DATE : **04-MAY-04**

TIME : **10.00**

TIME ALLOWED : **3 Hours**

04-N0013-3-40

TURN OVER

*Answer **FOUR QUESTIONS in total with TWO from each section.***
*ALL questions carry a total of **20 MARKS** each, distributed as shown* [ ]

SECTION A

1.

i) Describe the phenomenon of fluidization and the primary forces that act on a fluidized particle under equilibrium conditions. [4]

ii) Explain what the minimum fluidization and minimum bubbling velocities represent for a gas–solid fluidized bed system and the significance of the kinematic wave velocity for the stability of homogeneous fluidization. [6]

iii) Consider a packed bed of solid particles of density 2000 kg m^{-3} which occupies a depth of 0.6 m in a cylindrical vessel of inside diameter 0.1 m. The mass of solids in the bed is 5 kg. The fluidizing fluid is water having density 1000 kg m^{-3}.

a) Calculate the voidage of the packed bed, ε. [4]

b) Use a force balance over the bed to determine the bed pressure drop when fluidized. Assume in the calculation that the voidage at minimum fluidization ε_{mf} is equal to that of the packed bed, ε [6]

2.

i) Describe and sketch the "*bubble induced mechanism of mixing and solids circulation*". Describe how this is influenced by bed geometry, i.e. large shallow beds and thin deep beds. [6]

ii) Consider a bubbling fluid–bed containing sand particles of density 2500 kg m^{-3} which are fluidized using nitrogen at a superficial gas velocity of 0.48 m s^{-1}. Calculate the solids flux in the fluid–bed using the following data: [14]

voidage at minimum fluidization, $\varepsilon_{mf} = 0.45$
minimum fluidization velocity, $u_{mf} = 0.12$ m s^{-1}
bubble rise velocity, $u_b = 1.06$ m s^{-1}
fraction of solids travelling in the bubble wake, $\beta_w = 0.26$
fraction of solids travelling in the bubble drift, $\beta_d = 0.42$
consider that the two-phase theory applies and $Y = 1$ (where the coefficient Y indicates the deviation from the Two-phase theory)

The following balance may be applied to calculate the solid flux:

$$\begin{pmatrix}\text{mass}\\ \text{circulation}\\ \text{rate}\end{pmatrix} = \begin{pmatrix}\text{bulk}\\ \text{density of}\\ \text{dense phase}\end{pmatrix} \text{x} \begin{pmatrix}\text{fraction of bed}\\ \text{where solids}\\ \text{move upwards}\end{pmatrix} \text{x} \begin{pmatrix}\text{upwards}\\ \text{solids}\\ \text{velocity}\end{pmatrix} \text{x} \begin{pmatrix}\text{bed}\\ \text{cross}\\ \text{section area}\end{pmatrix}$$

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3.

i) A new fluid–bed process is being developed. In order to identify the operating conditions the particle fall velocity, u_t, has to be determined. Use the diagram attached, see Figure 1, to calculate u_t for the following gas–particle system:

d_p = particle diameter = 75 μm
ρ_p = particle density = 1770 kg m^{-3}
ρ_f = gas density = 1.22 kg m^{-3}
μ = gas viscosity = $1.8\text{x}10^{-5}$ kg m^{-1} s^{-1}
acceleration gravity = 9.81 m s^{-2} [8]

ii) The Richardson–Zaki equation is used in fluidization to describe homogeneous expansion. It relates the superficial gas velocity to the fluid bed voidage and particle terminal fall velocity. Write the Richardson–Zaki equation and using the data above, calculate the superficial gas velocity which is needed to expand the bed and obtain an average fluid–bed voidage $\varepsilon = 0.52$. Consider viscous flow regime. [8]

Use Figure 1 to check the fluidization regime that corresponds to the calculated superficial gas velocity. [4]

Attach the graph to the solution submitted.

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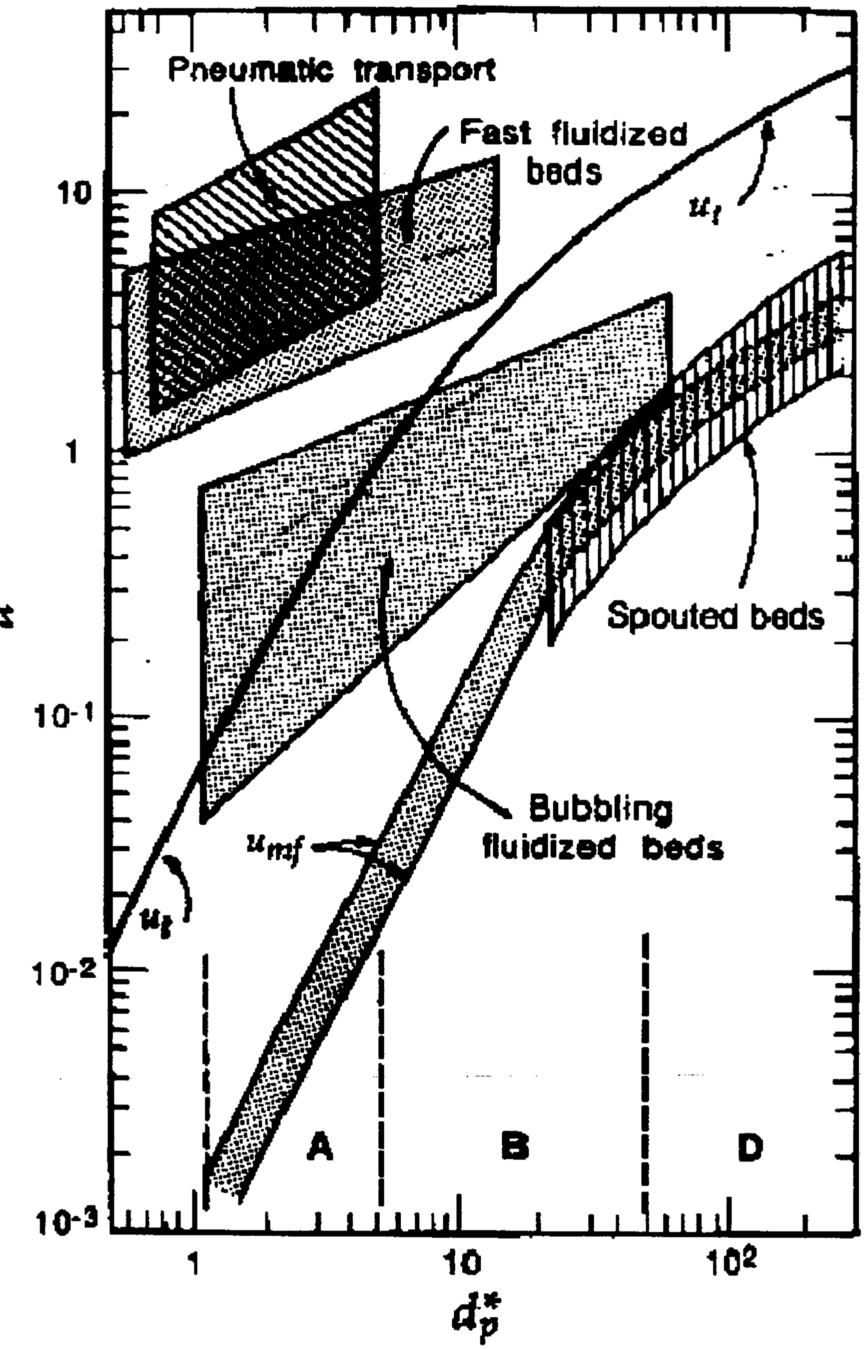

FIGURE 1
(Kunii, Levenspiel (1991) "Fluidization Engineering," Butterworth – Heinemann, London).

where:

$d_p^* = Ar^{1/3}$; $u^* = \dfrac{Re}{Ar^{1/3}}$; A, B, D refer to the Geldart classification of powders.

Re is the Reynolds number and

$$Ar = \frac{d_p^3 \rho_f (\rho_p - \rho_f) g}{\mu^2}$$

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SECTION B

4.

i) Describe briefly what you understand by the term polymorph. [4]

ii) You are presented with a chemical compound which exists in two polymorphic solid forms. What experimental techniques could you employ to distinguish the two forms? Explain exactly what information each technique would give you, and how the information would be used to distinguish the two forms. [6]

iii) You are given a sample of this compound that is believed to contain roughly equal proportions of the two polymorphic forms. For any *two* of the techniques above, describe how you would use the results obtained to confirm that both polymorphs are present in the sample and obtain a more accurate estimate of their proportions. You may assume that reference samples of the pure individual polymorphs are available. [6]

iv) The compound is an active ingredient of a new agrochemical preparation, and there is a requirement to manufacture one of the polymorphs in a pure form for formulation into the final product. Outline briefly the important factors that need to be considered in deciding which of the polymorphs to use. What measures can be taken in developing the crystallization process to maximise the probability of obtaining the specified solid form? [4]

5.

Explain the basis for crystallization from solution by briefly defining the terms *supersaturation*, *nucleation* and *crystal growth*. [3]

Define the terms *mass fraction* and *population density* as applied to particle size distributions. Sketch the CSD (crystal size distribution) of the product from an MSMPR (mixed-suspension, mixed-product-removal) crystallizer in terms of each quantity. [4]

State the population balance and show that the crystal size distribution from a continuous mixed-suspension, mixed-product-removal (MSMPR) crystallizer at steady state is given by:

$$n(L) = n^o \exp(-L / G\tau)$$

where $n(L)$ is the population density at crystal size L, n^o is the population density of nuclei, G (= dL/dt) is the overall linear growth rate and τ is the mean residence time in the vessel. [10]

Consequently, with the aid of two simple diagrams outline how nucleation and crystal growth rate data may be determined experimentally. [3]

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6.

The crystal size distribution (CSD) from a continuous mixed-suspension, mixed-product-removal (MSMPR) crystallizer at steady-state may be expressed by:

$$n(L) = n^0 exp\ (-L/G\tau)$$

where $n(L)$ is the population density at crystal size, n^o is the population density of nuclei, G is the overall linear crystal growth rate (m s^{-1}) and τ is the mean residence time in the vessel (s).

Show that the solids hold-up, M_T, in the slurry from a continuous mixed-suspension, mixed-product-removal (MSMPR) crystallizer at steady-state may be related to the crystallization kinetics and crystallizer residence time by:

$$M_T = 6f_v\rho n^o(G\tau)^4$$

where f_v is the volume shape factor, ρ is the crystal density. State clearly any assumptions that you may make.

[10]

An MSMPR crystallizer with a working volume V = 50 m^3 is operated at steady state with a nuclei population density of $n^o = 10^{10}$ μm^{-1} m^{-3}, an invariant crystal growth rate $G = 10^{-8}$ m s^{-1}, and a mixed product slurry removal rate Q = 50 m^3 h^{-1}. Estimate:

i) the solids content in the crystallizer (kg),
ii) the crystal production rate (kg hr^{-1})
iii) the dominant crystal size (μm)
iv) the percentage of crystals removed in the outflow by the time they have grown to 10μm.

The crystal density ρ = 2000 kg m^{-3} and the volumetric shape factor f_v = 0.5.

[10]

END OF PAPER