Daizo Kunii and Octave Levenspiel

FLUIDIZATION ENGINEERING*

Reviewed by S. S. Zabrodskii

The monograph Fluidization Engineering by the well-known scientists D. Kunii (Japan) and O. Levenspiel (USA) is of great interest to researchers working in this new field.

The authors' aim, as they express it in the preface of the book, that of emphasizing the engineering aspect, merits approval. Practical manuals on fluidization with a satisfactory physical theoretical basis are particularly essential.

Unfortunately, and somewhat contrary to the expressed aim, very little space is devoted to the design of equipment, and to descriptions, and critical appraisal of, the designs of the most important components.

The presentation of the material is successful – in the form of a textbook with numerous problems and examples "for the torture of students," in the authors' picturesque expression.

The book contains 15 chapters. The introductory account of the regions of application of fluidization and the macroscopic hydrodynamics of beds is followed by five chapters in which the hydrodynamic structure of the bed, interphase heat and mass transfer, and the course of catalytic reactions on a solid and fluidized catalyst are considered from the viewpoint of the authors' "bubbling bed model." The following chapters deal with heat transfer between beds and surfaces (Chap. 9), the elutriation and entrainment of particles by the gas stream (Chap. 10), the growth and reduction in size of the particles, and the distribution of their residence times in the bed (Chap. 11). The concluding chapters deal with such practical questions as the organization of the circulation of solids in a system (Chap. 12), the principles of design of beds for physical process operations (Chap. 13) and for the conduction of chemical reactions in the gas phase on a solid catalyst (Chap. 14), and also noncatalytic heterogeneous reactions (Chap. 15).

The authors clearly show that the effectiveness of interphase contact in physical and chemical processes in a fluidized bed is closely related to the nature of motion of the gas and particles. The authors examine this motion and contact processes from the common standpoint of the adopted bed model. This model is obtained by simplification of Davidson and Harrison's well-known "bubble theory," the use of some experimental data, and the neglect of others.

We will discuss some features of the proposed model, since it occupies a central place in the book. It is assumed that:

1. Near each of the numerous ascending bubbles the gas flow conforms to Davidson's well-known model with its distinction between slow and fast bubbles, surrounded by "clouds" of circulating gas.

2. In the proposed very simple model the size of the bubbles is assumed to be constant throughout the bed or in the section under consideration, and this is called the effective (theoretical) size. As evidence of the validity of this assumption Kunii and Levenspiel cite cases of fluidization in a packed bed, where the size of the bubbles is actually limited by the sizes of the packing elements, and also two reasons for slowing down of bubble growth in a free bed: the instability of large bubbles and the cessation of coalescence of the bubbles after reduction of their number due to preceeding coalescence. Unfortunately, the experimental data of Whitehead, Dent, and Bhat (1967) do not confirm this restriction of the growth of bubbles in

*Wiley, New York (1969).

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 19, No. 4, pp. 758-760, October, 1970.

a free bed. As regards fluidization in a packed bed we can expect that the action of the solid phase and gas is quite different from that in a free unimpeded bed.

3. The velocity of rise of a crowd of bubbles is greater than the velocity of a single bubble by an amount equal to the difference between the filtration velocity and the minimum fluidization velocity.

4. At fluidization numbers greater than 2 there are very few bubbles in the bed, and close to the grid large bubbles with very thin clouds are formed.

This assumption is wrong in principle because the fluidization number does not determine the hydrodynamic state of the bed (it depends greatly on the particle diameter).

5. As usual, the presence of solid particles in the bubbles is ignored, and the voidage of the emulsion "phase" is assumed to be equal to the voidage of the bed at the stability limit.

Kunii and Levenspiel then adopt several more "postulates."

1. Immediately above the gas-distributor the solids are entrained by rising bubbles like a wake. The wake is carried up the bed with the velocity of the bubble and is continuously exchanged with fresh emulsion material. The exchange rate depends on the fact that the solids enter the wake only from the space bounded by the gas-circulation cloud.

2. As a bubble rises, it pushes the emulsion aside and the solids passing close to the bubble enter its cloud and are shown into its wake, the breadth of which is approximately equal to the bubble diameter. The solids are completely mixed in the wake, and this gives rise to lateral mixing of the bed. Solids farther from the bubble are displaced somewhat as the bubble passes by and then return close to their original position. Lateral mixing of solids oscillating in this way is negligible.

3. Gas exchange between the bubbles and emulsion in the bed is assumed to be purely molecular. This does not correspond with the experimental data of Toei et al. (1968).

A fault of the Kunii and Levenspiel model is that it ignores special features of the exchange process in the lower part of the bed near the grid, but this is a fault of the models of other authors also.

As a result of the above-mentioned and other simplifying assumptions Kunii and Levenspiel derive design formulas and a consistent method of calculating several processes. The formulas contain only one quantity, which is difficult to determine, but it is, unfortunately, a basic one – the effective bubble size in the bed. In view of the assumptions made, an agreement between the calculated bubble size and the actual size would be accidental, as the authors themselves admit. In fact, the model at present can be used only for a qualitative analysis of the experimental data.

We can only wish for the realization of the authors' hope that there may be found a simple (as yet unknown) relationship between the calculated and actual bubble size, which would allow the model to be used for scaleup from laboratory apparatuses to large industrial plant and for quantitative engineering calculations of the kinetics of the physical and chemical processes occurring in a fluidized bed.

The bibliography in the book, given at the end of each chapter, contains approximately 360 references (the works are almost exclusively of Western and Japanese scientists). The incompleteness of the bibliography, especially as regards heat transfer between beds and surfaces, reduces the value of the monograph. The only cited Soviet work on these questions is that of Kharchenko and Makhorin (1964), which is an out-of-date treatment of experimental results, long rejected by the authors themselves.

Kunii and Levenspiel also overlook some interesting work of Japanese scientists. In particular, they make no mention of Yukio Tanaka's papers on electrothermal fluidized systems.

Recommended resistances for gas distributors are given without physical justification and no literature on this question is mentioned.

Nevertheless, Kunii and Levenspiel's book does give a basically true picture of the progress of Western countries and Japan in the field of fluidization. As distinct from other monographs on general questions of fluidization, the book devotes a great deal of attention to chemical reactions in a fluidized bed.

The authors give a great deal of space to the problem of the organization of reliable circulation of material in systems and correctly regard this question as one of the keys to the success of the introduction of any complex system.

This book fully deserves translation into Russian.

A. G. Shashkov and T. N. Abramenko

THERMAL CONDUCTIVITY OF GAS MIXTURES*

Reviewed by G. N. Dul'nev and Yu. P. Zarichnyak

Gas mixtures are widely used as raw material or are a final product in the chemical industry, or the working substance (heat-transfer medium) in power engineering and the newest fields of science and engineering (gas lasers). The thermal conductivity of gas mixtures depends on the properties of the components, their volume concentration, the temperature, and the pressure, and can vary by several orders. The unlimited combinations of effective parameters, the complexity of the design of experimental apparatuses, and the work entailed in conducting the measurements make experimental investigations of the thermal conductivity of gas mixtures very difficult. Hence, in addition to an improvement in the technique of measurement, the development of theoretical methods of calculating the thermal conductivity of gas mixtures on the basis of molecular-kinetic theory is of great value. A mixture of heterogeneous gases is regarded as a pseudohomogeneous gas, the parameters of which (dimension and mass of molecules, parameters of intermolecular interaction potential) are averaged by special methods. The solution of the integrodifferential Boltzmann equation for the energy fluxes through a layer of pseudohomogeneous gas leads to equations for the thermal conductivity of a gas mixture.

A great number of papers in our own and, in particular, in Western periodicals show an appreciable disagreement with the small number of monographs which can be recommended for practical acquaintance with methods of calculating the thermal conductivity of gas mixtures. In the small number of monographs on this question attention is centered on pure gases and the thermal conductivity of gas mixtures is dealt with cursorily without a detailed account of the physical nature of heat transfer in mixtures.

A. G. Shashkov and T. N. Abramenko's monograph Thermal Conductivity of Gas Mixtures is the most comprehensive Russian publication on this question and reflects the development of the molecular-kinetic theory of heat transfer in gas mixtures in the last decade.

The first chapter expounds the main ideas of the molecular-kinetic theory of heat transfer in gases.

The second and third chapters are devoted to a description of the present state of kinetic theory of monatomic and polyatomic gases and gas mixtures and methods of solving the integrodifferential equation of the gas state near equilibrium.

Different theoretical ideas relating to heat transfer in gas mixtures are compared in the fourth chapter. Methods of calculating the thermal conductivity of mixtures by means of exact, semiempirical, and empirical relationships are discussed. The results of calculations are compared with the extensive experimental data.

The fifth chapter describes the development of the theory of thermal conductivity of gas mixtures at low temperatures with the inclusion of quantum effects. It is shown that heat transfer at low temperatures is due mainly to the rotational degrees of freedom of the molecules, and the transitional degrees of freedom degenerate. One would like to see a further development of theory for the intermediate temperature region (between room and low temperatures) with due regard to the contribution of each of the heat transfer mechanisms.

*Energiya, Moscow (1970).

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 19, No. 4, pp. 761-762, October, 1970.

The sixth chapter is devoted to experimental methods of determining the thermal conductivity of gases and gas mixtures.

This book will certainly be of interest to a wide circle of scientific workers, engineers, and teachers and students in higher educational institutions.