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REVIEWS

Fluid-Bed Heat Transfer. By J. S. M. Botterill. Academic, 1975. 299 pp. £9.00.

Fluidization can be visualized in terms of a simple experiment in which a bed of solid particles is supported on a horizontal gauze in a vertical tube. Gas or liquid is then forced to flow upwards through the gauze, and so through the particle bed. This flow causes a pressure drop, and when the pressure drop across the bed is sufficient to support the weight of the particles the bed is said to be incipiently fluidized. Further increases in flow cause the bed to expand to accommodate the increase. The same temperature is quickly established throughout a fluidized bed because the general agitation of the particles disperses local regions of different temperatures. There is, moreover, a high rate of heat transfer to a solid object placed in the bed: the heat transfer coefficient is an order of magnitude greater in a fluidized bed than in a similar fixed bed of particles, and nearly two orders of magnitude greater than the walls–air coefficient in an empty vessel.

Three types of heat transfer in a fluidized bed can be distinguished: transfer between the bed and its containing walls; transfer between the bed and immersed surfaces; and transfer between the particles and the fluidizing gas or liquid. Dr Botterill's book provides a substantial review of these heat transfer phenomena, which form a research field that has given rise to several hundred publications during the last 25 years.

The book opens with a general account of gas fluidization, including a chapter on solids transport. This is followed by chapters on heat transfer mechanisms and heat transfer to immersed surfaces in fluidized beds. The early chapters on fluidization in general take up nearly half the present book but, as Dr Botterill explains, not of the book as originally conceived. It is Dr Botterill's hope, which I believe will be widely shared, that a section on the industrial applications of heat transfer in fluidized beds will be provided in due course by Professor Elliott of the University of Aston. It is arguable, though, whether in a book of this title and size the reader should have to wait to page 145 before there is a full-scale discussion of heat transfer as such. Nevertheless, the book's earlier chapters will undoubtedly be useful to those without ready access to other texts.

The many experimental situations of practical importance that require investigation have attracted many workers to study heat transfer in fluidized beds. In addition to heat transfer between the bed and its walls, heat transfer may occur between the bed and immersed tubes, which may be horizontal, or vertical, or have extended surfaces (e.g. fins). Heat transfer has also been investigated in mechanically stirred systems, in flowing gas–solids suspensions, and in liquid-fluidized beds. This book covers these and other aspects of the subject, and Dr Botterill is very fair in references to the work of others. Without doubt the book will be a valuable source of reference for research students about to start their work. But there is a small penalty to be paid. Passages in the book that give short accounts of several distinct pieces of research are not particularly easy to follow in a connected way. Also, in some cases, the evenhanded approach to earlier work may lead future workers to form too kind a view of minor contributions and so fail to give proper weight to work of more permanent significance. In Dr Botterill's defence, though, this research field is still fairly young and the landmarks have not yet clearly emerged. It is, incidentally, a pleasure to record here that the book makes a notable contribution to the subject by the effective way in which Russian work on heat transfer is discussed alongside that from the West. Previously, two substantial bodies of knowledge have stood apart in some isolation.

The book does not attempt to provide an extended treatment of the theoretical foundations of the subject. In my opinion, only in one case – in a description of an important paper by Dr Botterill himself (with Dr Williams) – is the heat transfer problem presented in sufficient depth for the reader to come close to the fundamental problems. However, in other cases, I judge Dr Botterill to have given sufficient information for the student to decide whether or not to go to the original papers. I would suggest, however, that there is a gap in the book which bears upon both theory and experiment: slug flow systems receive little attention. In slug flow, gas bubbles in a fluidized bed are comparable in size to the bed diameter and the system is reasonably stable and predictable. With regard to heat transfer it is possible with slug flow, first, to estimate the packet "contact time" of the model given by Mickley and Fairbanks much more readily than for normal bubbling beds. Attempts to do this have been reasonably successful, and they give encouragement to further work on "packet" models for heat transfer. Second, on the experimental side, it has become clear – particularly following work by Stewart in 1965 – that some laboratory experiments in the past have been carried out under a condition of slug flow which has been unappreciated by the experimentalists concerned. A knowledge of slug flow behaviour, therefore, can bear directly upon the interpretation of some early laboratory work on this subject.

The difficulty of comparing past work in this field hardly needs emphasis. Dr Botterill shows very effectively the chaotic state of the heat transfer correlations now available in the literature: the dependence of the heat transfer coefficient on particle size, for instance, has been found to vary inversely at powers from 0·23 to 0·96. Some comparisons between different workers in the past may have been particularly misleading, as this book points out, because experimental observations attributed to differences in (say) particle heat capacity may in fact have been caused by fundamental differences in the flow patterns of particles and gas caused by variations in gas distribution or equipment scale. It is perhaps surprising, in the face of the considerable uncertainties that surround the significant parameters effecting bed-surface heat transfer, that a good number of industrial applications have prospered. The reason, I think, lies in the graph illustrated on the cover sheet of the book. This shows that the heat transfer coefficient (in the absence of radiant transfer) commonly falls in the range 250–400 $W/m^2\,°C$. There are of course situations in which higher coefficients may be obtained, and it is usually prudent to think in terms of rather lower values as the scale of the equipment is increased. Nevertheless, unless it transpires that heat transfer is a limiting factor for design, it is often possible to make an estimate of the heat transfer coefficient for a given situation which is adequate for the purpose.

In my view this book is a necessary reference for fluidization research workers; it can be recommended for those in industry, research establishments and universities.

D. HARRISON

Dimensionsanalyse. By H. GÖRTLER. Springer, 1975. 247 pp. DM 58 or $23.80.

Although there are several books on dimensional analysis (e.g. by P.W. Bridgman, L. I. Sedov) written in or translated into English, this book appears to be the first one to be written in German. The first three chapters contain a detailed explanation of the definition of a physical dimension and of functions and equations which are "dimensionally homogeneous". In chapter 4 the fundamental theorem (π-theorem, sometimes known as Buckingham's theorem) of the theory of physical dimensions is introduced and two proofs are given which rely on a minimum of assumptions. In any physical problem which can be described by n functions x_j of m basic power products (e.g. of mass, length time) with the dimension $[x_j] = M_{jl}^{a_{jl}} \ldots M_{jm}^{a_{jm}}$, the rank r of the matrix (a_{jk}) plays an important part. The theorem states that any function $f(x_j)$, when non-dimensionalized (divided) by suitable powers of the x_j, can be expressed as a function $(G\pi_1 \ldots \pi_p)$, where the $p = n-r$ quantities π_i are non-dimensional "fundamental" power products of the x_j.

In chapter 5 the author gives a large number of examples in which the theorem is applied in order to obtain information on a physical problem. The first set of examples is taken mainly from solid mechanics and fluid dynamics and lead to "optimal" results (p small) with a closed formula with only some numbers to be incorporated being obtained. In a second set of examples the result of dimensional analysis is improved by using additional physical information, such as in the example of the Blasius laminar boundary layer in the flow past a flat plate. A third set of examples contains some useful instances where some of the basic quantities x_j are replaced by a smaller (or larger) number of quantites, e.g. the change from the usual physical system (mass, length, time) to the astronomical system (length, time) where the quantity "mass" is related to the other two by the law of gravitation. The reduction in the number m of the basic quantites x_j can lead to a larger value of p, i.e. a "weaker" statement, as is shown by describing the so-called Rayleigh's paradoxon.

In a final section the relation of dimensional analysis to "self-similarity" is shown, the latter in many cases being based on the reduction of a complicated system of partial differential equations to an ordinary differential equation. Also the importance of the π-theorem in "scaling", i.e. in model experiments at a different scale from the real problem, as in wind-tunnel experiments, is pointed out.

The book is suitable for undergraduates, since all the required mathematics are explained, and is also of interest to the experienced teacher, because of the many interesting examples and historical remarks included in the book.

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