Int. J. Multiphase Flow, Vol. 3, pp. 197–198. Pergamon/Elsevier, 1976. Printed in Great Britain.

BOOK REVIEW

Thermo-fluid dynamic theory of two-phase flow by M. Ishii. 1975. Eyrolles, Collection de la Direction des Etudes et Recherches d'Electricité de France.

Ishii wrote his book during his stay at Grenoble; he works at present at the A.N.L. This work, an important contribution to the development of basic formulation, is to be considered as being "upstream" the derivations Dr Bouré presented at the European Two-Phase Flow Group Meeting held at Haifa (1–5 June 1975). The main purpose of Bouré's paper was to show what has to be done to use the fundamental equations in the best way.

The book starts with the local instant formulation. This is the less original part of the study since it is in complete agreement with the works of Delhaye, Vernier and Bouré. It is based on the continuum approach: each subregion bounded by interfaces can be considered as continuum. Since an interface is a singular case of the continuous field, we have two different conditions at the interface. The balance at an interface which corresponds to the field equation is called a jump condition, whereas any additional information corresponding to the constitutive laws in space which are also necessary at interface, is called an interfacial boundary condition and restricts the kinematical, dynamical and thermal relations between the phases. They must satisfy the restriction imposed by the entropy inequality.

The formulation based on the local instant variables shows that the problem is a problem with multiple boundaries with the position of the interfaces being unknown, and as the local instant motions of the fluid particles are rarely required for engineering problems, the author is looking for proper averaging. A proper averaging would eliminate the local instant fluctuations but not the statistical properties of these fluctuations which influence the macroscopic processes.

There are several ways to average:

Eulerian average—Eulerian mean value

Function, $F = F(t, \mathbf{x})$;

Time mean value (temporal), $\dfrac{1}{\Delta t}\displaystyle\int_{\Delta t} F(t, \mathbf{x})\,\mathrm{d}t$;

Spatial mean value, $\dfrac{1}{\Delta R}\displaystyle\int_{\Delta R} F(t, \mathbf{x})\,\mathrm{d}R(\mathbf{x})$;

Volume, $\dfrac{1}{\Delta \nu}\displaystyle\int_{\Delta \nu} F(t, \mathbf{x})\,\mathrm{d}\nu$;

Area, $\dfrac{1}{\Delta a}\displaystyle\int_{\Delta a} F(t, \mathbf{x})\,\mathrm{d}a$;

Line, $\dfrac{1}{\Delta c}\displaystyle\int_{\Delta c} F(t, \mathbf{x})\,\mathrm{d}c$;

Statistical mean value, $\dfrac{1}{N}\displaystyle\sum_{n=1}^{N} F_n(t, \mathbf{x})$;

Mixed mean value, combination of above operations.

Lagrangian average—Lagrangian mean value

Function, $F = F(t, \mathbf{X})$; $\mathbf{X} = \mathbf{X}(\mathbf{x}, \mathbf{t})$;

Time mean value (temporal), $\dfrac{1}{\Delta t}\displaystyle\int_{\Delta t} F(t, \mathbf{X})\,\mathrm{d}t$;

Statistical mean value, $\dfrac{1}{N}\displaystyle\sum_{n=1}^{N} F_n(t, \mathbf{X})$.

Boltzmann statistical average

Molecular density function, $f = f(\mathbf{x}, \xi, t)$;

Transport properties, $\psi(t, \mathbf{x}) = \dfrac{\int \psi(\xi) f d\xi}{\int f\, d\xi}$.

The choice of averaging and instrumentation are closely coupled, since in general measured quantities represent some kinds of mean values.

The Eulerian time averaging is of course the most important, and has been used intensively in studying single phase turbulent flow. Ishii points out that there are two notable consequences in the time averaging when it is applied to a two-phase mixture:

(a) smoothing out turbulent fluctuations in same sense as in single phase flow;

(b) bringing two phases which are alternately occupying a volume element, into two continua simultaneously existing at same point with a properly defined expectation for each phase.

The constitutive laws should be expressed through the time mean values.

So, the author spends two chapters to establish the basic relations and balance equations in time average. He takes great care of the interfacial terms, velocity fields diffusion term and so on. He indicates what has to be done when singularities such as stationary interface or shock discontinuities are encountered.

After that he considers the Boltzmann statistical average which is useful for a highly dispersed flow where each quantity is considered as a lumped entity rather than as a distributed system itself.

The third part of the book is devoted to three-dimensional modeling based on time average. It concerns the two-fluid model and the diffusion model.

The two-fluid model is formulated by considering each phase separately. Thus, the model is expressed in terms of two sets of conservation equations governing the balance of mass, momentum and energy in each phase. However, since the averaged fields of one phase are not independent of the other phase, one has interaction terms: the transfer of mass, momentum and energy from the interfaces. Ishii studies these terms very carefully. As these quantities obey the balance laws at the interfaces, he derives the interfacial transfer conditions from the local jump conditions. Consequently six differential field equations with three interfacial transfer conditions govern the macroscopic two-phase flow systems.

Ishii points out that the two-fluid model is well suited to the studies of the local wave propagations and related stability problems. However if one is concerned with the total response of the two-phase mixture in a system rather than the local behaviour of each phase, the diffusion model is simpler and in most cases more useful for solving problems.

The diffusion model is expressed in terms of four field equations: the mixture continuity, momentum and energy equations, plus the diffusion equation.

In the two-fluid model Ishii gives some interesting considerations on the equation of state, the conduction heat transfer, turbulent fluxes, interfacial transfers, scaling parameters, and for the diffusion model he also spends twenty pages in considering the constitutive laws and scaling parameters.

In this book, there is no numerical example, no practical correlation, no experimental data, some rare sketches, but it gives quite an interesting basis for future work on applied two-phase flow mechanics.

Université Catholique de Louvain M. Giot

Boure, J. 1975 Mathematical modeling and the two-phase constitutive equations. European Two-Phase Flow Group Meeting, Haifa, 1–5 June.