Multiphase Science and Technology

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MULTIPHASE SCIENCE AND TECHNOLOGY

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Preface

Predictive methods for two-phase flow are assuming increased importance with the growing need for quantitative safety calculations on postulated accident scenarios (for instance in nuclear reactors). Though the capability to make complex calculations has taken a major leap forward with the availability of ever greater computer power, it remains a moot point whether the current predictive capability is on a sufficiently sound fundamental base to justify its use in supporting major technological decisions regarding operation and safety. It was with this background in mind that the Workshops on Two-Phase Flow Fundamentals were initiated in 1985 under the leadership of Professor Joseph Kestin (Brown University) and under the auspices of the US Department of Energy and the Electric Power Research Institute (EPRI).

The first Workshop took place in September, 1985 at Gaithersburg, Maryland. In this Workshop, it was agreed that the "six-equation model" (as currently used by most prediction codes) would be the main initial focus and presentations were made on key elements of the application of this model. Furthermore, it was agreed that an internationally approved collection of experimental Data Sets and Numerical Benchmark Exercises should be established with a strong emphasis on the fundamental aspects of the prediction problem. It was recognised that a number of International Standard Problems had already been set up with the specific objective of testing nuclear safety codes. However, it was felt that an approach through a more basic route would allow the clearer identification of the limitations of current prediction methods.

The presentations made at the First Workshop were published in Volume 3 of Multiphase Science and Technology together with 18 experimental Data Sets and 14 Numerical Benchmark Tests. This material has provided the basis for a more systematic approach to the evaluation of prediction methods and a selection of the Data Sets and all of the Numerical Benchmark tests were used as a basis for the Second Workshop which was held at Troy, New York in March, 1987. The Keynote Lectures given at this Workshop were published in Volume 5 of Multiphase Science and Technology; in this current volume, we present the results of the comparative calculation exercises carried out before and after the Second Workshop. It is through these exercises that the real status of prediction in our field can be judged. In recognition of the need for an increasing range of experimental Data Sets, a number of additional Data Sets were presented at the Second Workshop. After review, these were accepted by the Workshop and are also given for reference in the present Volume.

Part 1 of the present Volume presents the results of the Physical Benchmark Exercise. In this exercise (which was organised and collated by Professor T. G. Theofanous of the University of California at Santa Barbara) nine of the Data Sets were used for a series of comparative calculation studies.

Part 2 presents the 11 new Data Sets which represent firm and qualified data on a wide variety of two-phase flow phenomena ranging from simple cases such as bubbly flow in a tube to more complex cases such as flow in triangular ducts and level swell during blowdown. It is intended that these Data Sets (together with the ones published in Volume 3) should provide an archival reference against which calculation procedures can be systematically tested.

Part 3 presents the results of the Numerical Benchmark Exercise. This exercise was organised and collated by Professor D. B. Spalding of Imperial College, London. Here, all of the Numerical Benchmark Tests were attempted by a number of participants and the efficacy of the Tests in checking the numerical effectiveness of the methods used in computer solutions was well demonstrated.

Part 4 of this Volume gives descriptions of many of the computer codes that were used in the calculation exercises.

The amount of effort involved in the work described in this Volume is truly staggering. What have we learnt from it? The first and most straightforward lesson concerns the numerical basis of the calculations; have we calculated what we intended to in discretising the original equations? In general, the answer appear to be a qualified yes! There are many pitfalls in carrying out numerical calculations in two-phase flow but, provided proper care is taken in validating the numerical methods (and the present test cases should help in this) it does not appear that numerical problems present the greatest barrier to success in calculation.

An entirely spurious impression can be obtained of the accuracy of calculations in two-phase flow if the literature is examined. This is because the results are rarely published if the calculation fails and because, in any case, the methods contain sufficient adjustable parameters to bring them into line with limited ranges of data. The results presented in Part 1 of the present Volume depart from the usual pattern in that both successes and failures are given equal prominence. The results are very illuminating indeed! Methods which purport to have general applicability give reasonable results for complex cases for which they have been adjusted but fail to predict simple cases such as pressure drop in fully developed flow in a tube. So what is going wrong?

When it is realised that it is impossible to predict from first principles even single phase turbulent flows at Reynolds numbers in the usual range of interest in engineering systems, perhaps our failure with two-phase flow is not surprising. However, as is being increasingly demonstrated in Computational Fluid Mechanics (CFD) for single phase flow, a phenomenological understanding of the nature of the flow can lead to better predictions of engineering significance. It is the failure to develop such a sound phenomenological understanding of two-phase flows which may lie at the heart of the problem. One difficulty here is the straightjacket imposed by limited models such as the six-equation model itself. It may be simply impossible to represent the flows adequately within the confines of such a model.

However, one should not take too gloomy a view of the situation; the understanding and prediction of two-phase flows is seen to present a fascinating and rewarding subject for the future. We can only hope that the present Volume will help to provide a realistic and useful starting point for the difficult and interesting journey ahead.

In closing, we would like to thank all those who have taken part in the work reported in this book. In particular, we would like to thank Professors Theofanous and Spalding who led the calculation exercises and Professor Lahey of Rensselaer Polytechnic Institute who organised the Second International Workshop on which much of the material here is based.

The Editors

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