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Policy Statement on Numerical Accuracy

The purpose of this statement is to establish and clarify acceptable standards for the publication of numerical results. It supplements the previously established JHT Policy on Reporting Uncertainties in Experimental Measurements and Results (1). In developing the current policy, the policy statement on control of numerical accuracy adopted by the ASME Journal of Fluids Engineering (2) was consulted, as well as similar policy statements currently under consideration by the AIAA journals and the International Journal for Numerical Methods in Fluids. We appreciate the willingness of those involved with the development of these latter policies to share their thinking with us and to allow our adoption of specific elements of their policy statements. Succinctly stated, the editorial policy of the JOURNAL OF HEAT TRANSFER regarding the review and publication of numerical studies is as follows:

NOTE: The JOURNAL OF HEAT TRANSFER will not accept for review or publication any manuscript reporting the numerical solution of a heat transfer problem that fails to establish adequately the accuracy of the computed results.

The implementation of this policy will be at the discretion of the editor and associate editors in association with the reviewers, and will be guided, in essence, by the considerations set forth below and by the view attributed to Kline (3), in the context of experimental uncertainty analysis, that ". . . any appropriate analysis is far better than none as long as the procedure is explained."

To be specific, all manuscripts submitted for review that include numerical simulations must contain the following essential elements:

- A problem statement that is of sufficient clarity and completeness to allow the reproduction of the results by informed readers. As a minimum, this should include a statement of the governing equations solved, all relevant boundary and initial conditions, and values of associated physical and numerical parameters. Values for any adjustable or arbitrary parameters employed to obtain the solution must be explicitly given.
- A description of the solution technique employed. If a standard method is used, the description can be via reference to appropriate prior publications. If a new method is introduced, the description must be sufficiently complete to allow implementation of the numerical scheme and replication of relevant results by informed readers.
- The numerical solution must be supplemented with acceptable accuracy estimates for both the method employed and the results presented. A single calculation using a fixed discretization will not be acceptable, since no error estimate can be inferred from such a calculation.

Authors may use any appropriate method for the estimation of errors. One, or more, of the following approaches may be useful in this regard:

- Comparison of numerical results with those from a sufficiently similar model problem available in the literature, possessing a known exact or highly accurate approximate analytical solution; or with an established, high-accuracy, fine-grid, numerical benchmark solution of the same, or closely similar, problem.
- A precisely defined and documented grid refinement or grid coarsening study. Marginal refinement showing a qualitative convergence trend is not acceptable. Other numerical and arbitrary parameters such as time step, convergence criterion, and boundaries of the computational domain should also be varied to ensure that the results are independent of these quantities.
- Comparison with reliable experimental results that possess an associated established uncertainty.

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Noting "reasonable agreement" with experimental data is not, in general, sufficient justification for acceptance of numerical results, especially when adjustable parameters are involved. Numerical and experimental results may be plotted or tabulated to indicate the level of agreement.

In the approaches described above, references to grid refinement are intended to be interpreted in a general sense to include numerical methods that are not explicitly dependent on a computational grid in the manner typically associated with, say, finite difference methods. For example, grid-free methods would require modification of the number, or size, of discrete elements in the computation to establish error estimates. An additional comment is in order regarding comparisons of numerical results with experimental data. It is recognized that, when the results of a numerical simulation are compared with experimental data, it may not be possible to separate errors in modeling from those associated with the numerical method. In these situations, a separate estimate of the numerical error should be established. In rare situations where none of the above approaches can be satisfactorily employed to establish the accuracy of the results, other methods of error estimation acceptable to the editor, associate editors, and reviewers may be appropriate. For an illustration of many of the elements involved in establishing the accuracy of a numerical solution, the study of natural convection reported by deVahl Davis (4), or the method discussed by Roache(5) for the uniform reporting of grid refinement studies may be consulted.

By implementation of this policy, it is the intent of the editorial board to establish guideline requirements for the publication of numerical results and to enhance the quality of publications involving numerical simulations. It is not our intent to effect a significant increase in the length of papers published in the JOURNAL OF HEAT TRANSFER, or to impose excessive requirements on prospective authors. Rather, we hope to elicit a "good faith" effort from authors to establish the accuracy of their numerical simulations.

The Editorial Board

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