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RECENT ADVANCES IN THE COMMIX AND BODYFIT CODES

by

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I. General Background

Tw eral-purpose computer programs for thermal-hydraulic analysis have been deve! ped. One is the COMMIX (COMponent MIXing) code[1,2,3]. The other one is the BODYFIT (BOunDary FITted Coordinate Transformation) code[4,5]. Solution procedures based on both elliptical and parabolic systems of partial differential equations are provided in these two codes. The COMMIX code is designed to provide global analysis of thermal-hydraulic behavior of a component or multicomponent of engineering problems. The BODYFIT code is capable of treating irregular boundaries and gives more detailed local information on a subcomponent or component. These two codes are complementary to each other and represent the state-of-the-art of thermal-hydraulic analysis. Effort will continue to make further improvements and include additional capabilities in these codes.

A. COMMIX Code

The COMMIX code employs a new porous media formulation[6,7] which is rigorously derived through local volume averaging. This new porous media formulation uses the concepts of volume porosity, directional surface permeabilities, distributed resistance, and distributed heat source or sink. In the conventional porous-media formulation[8,9], only volume porosity, distributed resistance, and distributed heat source or sink are used. Volume porosity is defined as the ratio of the volume occupied by fluid in a control volume to the total control volume. Directional surface permeability is similary defined as the ratio of flow area of a control surface in the j direction to the total control surface in the j direction. The concept of directional surface permeabilities is new. In thermal-hydraulic analysis, resistance (or friction factor) is in general not well defined for most engineering applications. Directional surface permeabilities are a function of geometry and are, in general, known. This new porous media formulation uses both distributed resistance and directional surface permeabilities for modeling velocity and temperature fields in anisotropic media. This is in contrast to the conventional porous media in which only distributed resistance is used. Thus, any error in estimating resistance will not entirely be reflected in the results using the new porous media formulation, but will be in the conventional porous media formulation. The concept of directional surface permeabilities greatly facilitates modeling of velocity and temperature fields in anisotropic media and, by a judicious choice of directional surface permeabilities, it improves resolution, accuracy, and momentum transfer.

This new porous media formulation represents the first unified approach to thermal hydraulic analysis. It can readily be shown that both the conventional porous media formulation and the continuum formulation are a subset of this new porous media formulation. The COMMIX code has a wider range of applicability than any other comparable code in existence. It is capable of solving thermal hydraulic problems involving either a single component, such as a rod bundle, reactor plenum, piping system, heat exchanger, etc., or a multicomponent system which is a combination of these components.

B. BODYFIT Code

The BODYFIT code uses a boundary fitted coordinate transformation which is capable of transforming any complicated geometry in a physical domain to either rectangular or cylindrical shape in the transformed space. The unique advantage of this transformation is that all physical boundaries are coincident with the computational grids; thus, it will give an accurate numerical solution to the problem under investigation. As an example, for rod bundle geometries, an accurate representation of rod boundary conditions in a rod bundle calculation has not been possible until the recent development of the BODYFIT code. The BODYFIT code enables a true rod bundle benchmark calculation for the first time. For laminar flow, there is absolutely no assumption used in the analysis, and only rod bundle geometry must be specified, along with coolant thermal physical properties. For turbulent flow, the normal closure problem is encountered in the turbulence modeling, and empiricism is unavoidable. Since the BODYFIT code is in the initial stage of development, the full potential of benefits derived from this work remains to be realized.

This paper describes the development of the COMMIX and BODYFIT codes which are limited to the scope of USNRC sponsorship. The work sponsored by USDOE on heat exchangers will not be described here. Also, the on-going work with EPRI on pressurized thermal shock using the COMMIX code as well as the BODYFIT-2PE (2PE denotes 2-phase flow, Partially Elliptical solution scheme) code development will not be discussed here.

II. Current Status

A. COMMIX Code

A new version of the COMMIX-1A code[3] has been released to the public through the USNRC's approval. This version is capable of analyzing "all" single-phase problems with complex geometries. A two-phase version of the COMMIX code, i.e., COMMIX-2, is still under development and is anticipated for limited distribution by the end of FY 83.

B. BODYFIT Code

Up to now, the BODYFIT code development is limited to the thermal hydraulic analysis of rod bundles. The BODYFIT-1FE (1FE denotes 1-phase, Fully Elliptical approach) code has been released through the USNRC's approval. A number of users have been actively using this code and the feedback information from these users is encouraging and positive. A spin-off benefit from the BODYFIT-1FE code is the development of the BODYFIT-2PE (2PE denotes 2-phase, Partially Elliptical approach) which is sponsored by EPRI. The BODYFIT-2PE employs the HEM model with an algebraic slip, and its documentation has been completed. Results from BODYFIT-2PE are also very encouraging and positive, especially in terms of running time which is comparable to the conventional subchannel analysis.

III. Recent Advances

A. COMMIX Code

The following significant advances have been made in the COMMIX code recently:

1. Completed a multiphase formulation via local volume averaging and delineated assumptions used in the "current accepted" two-phase flow equations.

2. Initiated an extension of the local volume averaging to the local volume and time averaging for multiphase formulation. Significant progress has been made; the deviation from an average of a product to a product of averages can be resolved, at least in theory, by using local volume and time averaging.

3. Implemented the two equation (k-ε) turbulence model, where k is the turbulence kinetic energy, and ε is the rate of dissipation of k.

4. Provided two numerical solution technique options. One is the semi-implicit scheme which is a derivative of the IMF (Implicit MultiField) method; the other is the fully implicit scheme which is an extension of SIMPLER (Semi-Implicit Pressure Linked Equation Revised) algorithm.

B. BODYFIT Code

1. Developed a new pressure correction plane-by-plane iterative scheme in the BODYFIT code. Significant reduction in computer running time to obtain a converged solution has been achieved.

2. Developed a generalized coordinate transformation scheme for arbitrary three-dimensional geometries.

IV. Future Effort

Following is a list of action items which we will be working on for further development of the COMMIX and BODYFIT codes:

1. Develop an efficient and robust numerical solution scheme for a multiphase flow system and optimize computer storage.

2. Simplify input (using CAD/CAM) and make the codes more user oriented.

3. Minimize numerical diffusion.

4. Improve physical models such as interfacial exchange of mass, momentum, and energy, and continue code validation.

5. Extend COMMIX multicomponent capability into a full 3D system code.

6. Implement the quasi-continuum formulation into the BODYFIT code.

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