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Current status of development of 3D DNS CONV-3D code: one- and two-phase flow models

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In IBRAE RAN in "Codes of New Generation"subproject of "Proryv"project one- and two-phase models are being developed to simulate heat and mass transfer processes in the separate elements of nuclear reactor. Those models are realized in the LES and DNS CONV-3D code.
The one-phase models are based on the algorithms with small scheme diffusion, for which the discrete approximations are constructed with use of finite-volume methods and fully staggered grids. For solving convection problem the regularized nonlinear monotonic operator-splitting scheme has been developed. The Richardson iterative method with FFT solver for Laplace's operator as preconditioner is applied for solving pressure equation. Such approach to the elliptical equations with variable coefficients gives multiple acceleration in comparison with the usual conjugate gradients method. For modeling of 3D turbulent flows both DNS and LES approaches are used.
The one-phase module of CONV-3D code is fully parallelized and has perfect scalability, thus it is effective on high-performance computers such as "Lomonosov"(MSU, Russia). The one-phase module has been validated against data of well-known and just got experimental data for various liquids, including lead and sodium used as coolants, in a wide range of Rayleigh numbers between 10^6 and 10^16, and Reynolds numbers in the range of 10^3 –10^5.
The two-phase models take into account interphase heat and mass transfer, stratification of the two-phase flow and separation of the gas component through the interface using equations of state such as condensed gas and the Noble-Able. The two-phase module in CONV-3D code is fully parallelized and has perfect scalability on a CPU and GPU systems. The algorithm of two-phase module is based on the use of HLL (Harten-Lax-van Leer) and HLLC (Harten-Lax-van Leer-Contac) solvers and two-step MUSCL (Monotonic Upstream-centered Scheme for Conservation Laws) predictor-corrector. The validation base includes experiments in which the heat and mass transfer and sodium boiling in the pipes were investigated.
This contribution presents several examples of code application for solving such problems as flow in fuel assemblies, tubes and ring channels, as well as natural convective flows in the elements of reactor. The results of two-phase flows modeling on the series of tests, including the problem of sodium boiling in a round pipe, are also shown.
In all cases the good agreement of numerical predictions with experimental data has been found, that specifies the applicability of the developed CONV-3D code to solve CFD problems for designing and operating NPPs.

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