An opportunity to use non-primitive variables for solution to three-dimensional convective flow and heat transfer problems

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Abstract. It is well-known that stream function is absent in the case of 3D fluid flow and heat transfer problems. Therefore, it is impossible to employ the simple generalization of numerical technique considered for 2D problems to the case of 3D boundary-value problems. At the same time, it is possible to exclude the pressure field for 3D problems using the vector potential functions and vorticity vector. An introduction of such new functions leads to the formulation of seven governing equations for the solution to fluid flow and heat transfer problems. These equations include three equations for the vector potential functions, three equations for the vorticity vector components and an energy equation. While in the case of primitive variables the governing equations include only five equations (continuity equation, three motion equations and an energy equation). Taking into account such difference, it seems that the computational time will be high for the non-primitive variables. In the case of natural convection combined with thermal surface radiation within a differentially-heated cubical cavity it has been shown that using non-primitive variables and finite difference technique allows reducing the computational time due to a lack of the global iterations that should be used in the case of primitive variables and finite volume method. During the second lecture the transformation of governing equations will be presented combined with original difference schemes for an approximation of convective and diffusive terms to solve 3D boundary-value problems. As an illustration, some interesting problems on natural convection in cubical cavities filled with porous medium or nanofluid will be considered.

Keywords: 3D boundary-value problem, vector potential functions, vorticity vector, finite difference method, natural convection