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Numerical-Value Perturbation Method with Application of Solving Convective-Diffusion Integral Equation

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Abstract

The convective-diffusion equation is of primary importance in such fields as fluid dynamics and heat transfer. In the numerical methods solving the convective-diffusion equation, the finite volume method can use conveniently diversified grids (structured and unstructured grids) and is suitable for very complex geometry. The disadvantage of FV methods compared to the finite difference method is that FV-methods of order higher than second are more difficult to develop in three-dimensional cases. The second-order central scheme (2cs) offers a good compromise among accuracy, simplicity and efficiency, however, it will produce oscillatory solutions when the grid Reynolds numbers are large and then very fine grids are required to obtain accurate solution. The simplest first-order upwind (1UW) scheme satisfies the convective boundedness criteria; however, its numerical diffusion is large. The power-law scheme, QUICK and second-order upwind (2UW) schemes are also often used in some commercial codes. Their numerical accurate are roughly consistent with that of 2CS. Therefore, it is meaningful to offer higher-accurate three point FV scheme.

In this paper, the numerical-value perturbational method suggested by Zhi Gao is used to develop an upwind and mixed FV scheme using any higher-order interpolation and second-order integration approximations, which is called perturbational finite volume (PFV) scheme. The PFV scheme uses the least nodes similar to the standard three-point schemes, namely, the number of the nodes needed equals to unity plus the face-number of the control volume. For instance, in the two-dimensional (2-D) case, only four nodes for the triangle grids and five nodes for the Cartesian grids are utilized, respectively. The PFV scheme is applied on a number of 1-D problems, 2-D and 3-D flow model equations. Comparing with other standard three-point schemes, The PFV scheme has much smaller numerical diffusion than the first-order upwind(1UW) scheme, its numerical accuracy are also higher than the second-order central scheme(2CS), the power-law scheme (PLS), the QUICK scheme and the second-order upwind(2UW) scheme.

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