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Effects of inner iteration times on the performance of IDEAL algorithm ☆

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ABSTRACT

An efficient segregated algorithm for non-linear incompressible fluid flow and heat transfer problems, called IDEAL (Inner Doubly-Iterative Efficient Algorithm for Linked-Equations) for short, was proposed in reference [9]. Subsequently, it was extended to the 3D staggered/collocated grid systems. IDEAL includes inner doubly-iterative processes for solving pressure equations at each iteration level, and it could adjust the inner iteration times to control the convergence rate and the stability of iteration process, which is greatly different from other segregated algorithms. The objective of this paper is to analyze the effects of inner iteration times on the performance of IDEAL by four incompressible fluid flow problems, two of which belong to open systems, and the others refer to closed systems. It is found that: (1) the robustness of IDEAL is enhanced greatly with the increase of inner iteration times; (2) at the same time step multiple, the outer iteration number decreases with the increase of inner iteration times and the computation time is not related to the inner iteration times; (3) at the optimal time step multiple, the large inner iteration times of 4&4 and 7&7 could reduce the outer iteration number by about 70% and the computation time by about 40% over the small inner iteration times of 1&1.

1. Introduction

In 1972 the first pressure-correction method, SIMPLE, was proposed by Patankar and Spalding [1]. The major approximations of SIMPLE are: (1) the initial pressure field and velocity field are assumed independently; (2) the effect of velocity corrections of the neighboring grids is not considered to simplify the solution procedure. These two approximations do not affect the final solutions when the solution is converged [2], but influence the convergence rate and stability of the solution. Since the birth of SIMPLE, many modified methods, such as SIMPLER [3], SIMPLEC [4], SIMPLEX [5], PISO [6], CLEAR [7,8] etc., have been proposed to overcome the shortcomings of the two approximations. Unlike other algorithms, CLEAR does not introduce the pressure correction, improving the intermediate velocity by solving a pressure equation to make the algorithm fully implicit since there is no term omitted in the derivation process. However, the robustness of CLEAR is somewhat weakened by directly solving the pressure equation. To overcome this disadvantage, IDEAL (Inner Doubly-iterative Efficient Algorithm for Linked-equations) was proposed in [9,10]. Subsequently, it was extended to the 3D staggered/collocated grid systems [11–13].

IDEAL includes inner doubly-iterative processes for solving pressure equation at each iteration level. The first inner iteration time N1 and the second inner iteration time N2 (hereafter named as N1&N2) could be adjusted to control the convergence rate and the stability of iteration process, which is significantly different from other segregated algorithms. In previous articles about IDEAL [11–13], different N1&N2 are applied corresponding to different ranges of time step multiples. As the most crucial adjustable parameters, N1&N2 have great effect on the performance of IDEAL. However, there is little analysis in this aspect. In order to gain further insight into IDEAL, we study the effect of N1&N2 on the performance of the algorithm systematically in this paper.

2. Brief review of IDEAL

The details of the implementations of IDEAL for incompressible steady laminar flow in 3D Cartesian coordinates have been well-documented in reference [11]. Here, we briefly review the solution process of IDEAL as follows.

Step-1: Assume an initial velocity field.
Step-2: Calculate the coefficients and source terms of the discretized momentum equations based on the initial velocity field.
Step-3: Solve the pressure equation iteratively until the iteration time equals to the pre-specified value of N1. Once the first inner

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