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Algebraic Splitting Methods for the Steady Incompressible Navier Stokes Equations at Moderate Reynolds Numbers

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Abstract

The unsteady incompressible Navier-Stokes equations in primitive variables are often numerically solved by segregating the computation of velocity and pressure, according to either functional analysis arguments following the pioneering work of A.J. Chorin and R. Temam (STD, Split-Then-Discretize paradigm) or linear algebra arguments based on the inexact block factorization of the discretized problem (DTS, Discretize-Then-Split paradigm). The presence of the time derivative allows for the calibration of an appropriate approximation of the pseudo-differential operator of the pressure problem and excellent results in terms of both accuracy and efficiency have been obtained as witnessed by the abundant literature. The extension of the same segregated approach to the steady Navier-Stokes equations is unclear, unless a pseudo-time advancing formulation is undertaken. In this paper we present a methodology for a segregated computation of the primitive variables in a genuinely steady formulation, so to avoid iterations to get to the steady limit. The approach is largely inspired by the algebraic factorization of the unsteady problem (DTS approach), yet we detail specific settings required by the absence of the velocity time-derivative. The basic idea relies on the introduction of some parameters in a modified Picard linearization. We discuss stability bounds and the convergence of the segregated method to the unsplit solution. Several numerical results on different test cases confirm the efficiency of the procedure.

1. Introduction

The steady incompressible Navier-Stokes equations are receiving increasing attention as they are used also in fields where traditionally unsteady models are considered appropriate. In fact, sometimes time averaged information can be properly retrieved by a suitable steady computation, with the advantage of reducing computational costs (see e.g. [1]). This is particularly of interest when computation time is a sensible aspect, as in medical applications of computational fluid dynamics with a strong clinical orientation.

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