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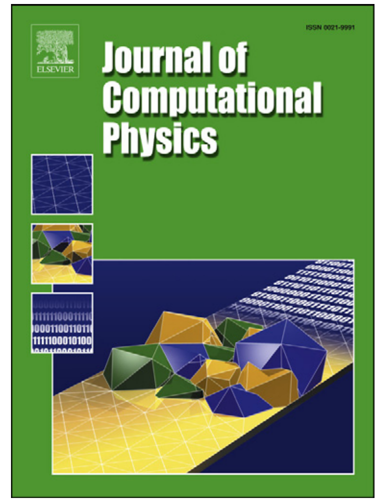

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Stabilisation of discrete steady adjoint solvers

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Abstract

A new implicit time-stepping scheme which uses Runge-Kutta time-stepping and Krylov methods as a smoother inside FAS-cycle multigrid acceleration is proposed to stabilise the flow solver and its discrete adjoint counterpart. The algorithm can fully converge the discrete adjoint solver in a wide range of cases where conventional point-implicit methods fail due to either physical or numerical instability. This enables the discrete adjoint to be applied to a much wider range of flow regimes. In addition, the new algorithm offers improved efficiency when applied to stable cases for which the conventional Block-Jacobi solver can fully converge. Both stable and unstable cases are presented to demonstrate the improved robustness and performance of the new scheme. Eigen-analysis is presented to outline the mechanism of the adjoint stabilisation effect.

Keywords: Reynolds-Averaged Navier-Stokes, Discrete Adjoint, Implicit, GMRES, multigrid, FAS-cycle

1. Introduction

The adjoint method is an essential ingredient of gradient-based steady-state CFD shape optimisation as it allows the computation of the gradient of an objective function with respect to a large number of design variables at near constant computational cost comparable to that of the flow solution. Two approaches are most prominently used to develop adjoint codes, the continuous and the discrete adjoint approach [1, 2, 3, 4]. The continuous adjoint approach re-discretises the adjoint PDE, which offers the possibility to optimise and/or stabilise the adjoint solver by tuning the discretisation. The steady-state discrete adjoint starts from the discretised equations which are then linearised around the converged steady state flow field and transposed. This ensures that the computed gradients are the exact gradients of the discrete model, which is a very desirable property: the discrete gradient is then exactly zero where the flow

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