A Higher Order Time Integration Algorithm For The Simulation Of Non-Linear Fluid-Structure Interaction

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For many engineering applications, problems related to fluid-structure interaction (FSI) are crucial for an efficient and safe design. For instance light-weight airplanes, long-span suspension bridges and modern multi-megawatt wind turbines are susceptible to dynamic instability due to aeroelasticity. Recent advances in computer power allow the computation of fluid-structure interaction by combination of a separate flow and structural solver. However, unsteady simulations are still very demanding, resulting in long simulation times. In order to increase computational efficiency, the application of higher order time integration methods is considered. For simulation of flows it is already shown that even for engineering levels of accuracy, higher order time integration schemes are more efficient [1]. Special care has to be paid to the coupling of the flow and structure solver to avoid loss of accuracy.

For the time integration additive Runge-Kutta (ARK) [2] methods are considered. Originally these methods were designed such that stiff terms are integrated by a stiffly-accurate explicit, singly diagonally implicit Runge-Kutta (ESDIRK) method, while the nonstiff terms are integrated by a traditional explicit Runge-Kutta (ERK) method. However, in fluid-structure interaction we just consider the regular flow and structural equations and the coupling terms due to the interaction. The regular flow and structural solvers use the ESDIRK scheme for the time integration. The ESDIRK methods are *L*-stable and have vanishing stability functions for very large values of the stiff scaled eigenvalue and retain high stability efficiency in the absence of stiffness. This makes them ideal for engineering applications since the time step is limited by accuracy rather then stability issues. The coupling terms at the interface are integrated by the ERK scheme. The resulting implicit/explicit (IMEX) scheme is applied to the one-dimensional piston problem. Results on a linear system already showed that large efficiency gains can be made compared to the popular second order backward differentiation formula (BDF) scheme.

In this paper we extend the analysis to the non-linear piston problem and we present an algorithm to retain the higher order of the scheme without the need for sub-iterating. We present and discuss the results for the non-linear piston problem.

[1] H. Bijl, M.H. Carpenter, V.N. Vatsa, and C.A. Kennedy, *Implicit time integration schemes for the unsteady compressible Navier-Stokes equations: laminar flow*, Journal of Computational Physics, 179, (2002), 1-17.
[2] C.A. Kennedy and M.H. Carpenter, *Additive Runge-Kutta schemes for convection-diffusion-reaction equations*, Appl. Num. Math., 44(1-2), (2002), 139-181.