

Aerospace Engineering Master's Defense

Autonomic Closure in Reynolds-Averaged Navier-Stokes (RANS) Simulations of Turbulent Flows

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abstract

Reynolds-averaged Navier-Stokes (RANS) simulation is the industry standard for computing practical turbulent flows -- since large eddy simulation (LES) and direct numerical simulation (DNS) require comparatively massive computational power to simulate even relatively simple flows. RANS, like LES, requires that a user specify a "closure model" for the underlying turbulence physics. However, despite more than 60 years of research into turbulence modeling, current models remain largely unable to accurately predict key aspects of the complex turbulent flows frequently encountered in practical engineering applications. Recently a new approach, termed "autonomic closure", has been developed for LES that avoids the need to specify any prescribed turbulence model. Autonomic closure is a fully-adaptive, self-optimizing approach to the closure problem, in which the simulation itself determines the optimal local, instantaneous relation between any unclosed term and the simulation variables via solution of a nonlinear, nonparametric system identification problem. In principle, it should be possible to extend autonomic closure from LES to RANS simulations, and this thesis is the initial exploration of such an extension. A RANS implementation of autonomic closure would have far-reaching impacts on the ability to simulate practical engineering applications that involve turbulent flows. This thesis has developed the formal connection between autonomic closure for LES and its counterpart for RANS simulations, and provides a priori results from FLUENT simulations of the turbulent flow over a backward-facing step to evaluate the performance of an initial implementation of autonomic closure for RANS. Key aspects of these results lay the groundwork on which future efforts to extend autonomic closure to RANS simulations can be based.