# Validation and enhancement of detached-eddy simulation in OpenFOAM


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## Abstract


Reynolds-averaged Navier–Stokes (RANS) models are the most widely-used turbulence treatment approach in industrial applications. Although offering greater accuracy, large-eddy simulation (LES) is associated with greater computational cost, rendering the approach unfeasible in many situations. Recent research efforts have therefore focussed on a family of hybrid RANS-LES methods intended to bridge the gap between these methodologies. Of these, perhaps the most widespread is detached-eddy simulation (DES) [5,6], in which attached boundary layers are modelled using RANS and regions of separated flow resolved by LES. DES has been shown to deliver significantly enhanced results compared to RANS at a fraction of the cost of LES, particularly for flows dominated by large-scale separation.

The implementation of DES in OpenFOAM (OF) still exhibits some shortcomings. First and foremost, no appropriate numerical convection scheme is available to reconcile the conflicting demands typically placed by RANS and LES. Secondly, it is important to offer DES formulated for a range of underlying RANS models, however only DES variants based on the Spalart–Allmaras (SA) model are available. Finally, the appropriate value of the DES model constant, $C_{\mathrm{DES}}$ is known to be highly sensitive to numerical details and we are unaware of any calibration carried out using OF.

The paper presents the current status of work intended to address these issues together with other code adjustments for the general solution procedure. We apply the lessons learned from our research experience with DES [1–4] to undertake a thorough and systematic validation and enhancement of its implementation in OF. Firstly, the suitability of the OF numerical schemes for LES is assessed on the basis of canonical flows. A calibration of $C_{\mathrm{DES}}$ is then conducted against decaying isotropic turbulence and a DES formulation for a further RANS model is implemented. The hybrid numerical convection scheme of Travin et al. [7] is furthermore incorporated. This scheme provides a localised flux blending (with blending function $\sigma$) between robust upwind-based schemes ($\sigma = 1$) in areas of unidirectional flow or relatively coarse grids, whereas low-dissipative central differencing ($\sigma = 0$) is used in areas of finer grids, higher vorticity and lower strain. The new features are tested for the complex, highly-unsteady flow around a NACA0021 airfoil in deep stall ($\alpha = 60°$, Re = 270000). The results are compared with experiments and verified against existing authoritative DES results from other solvers [3].


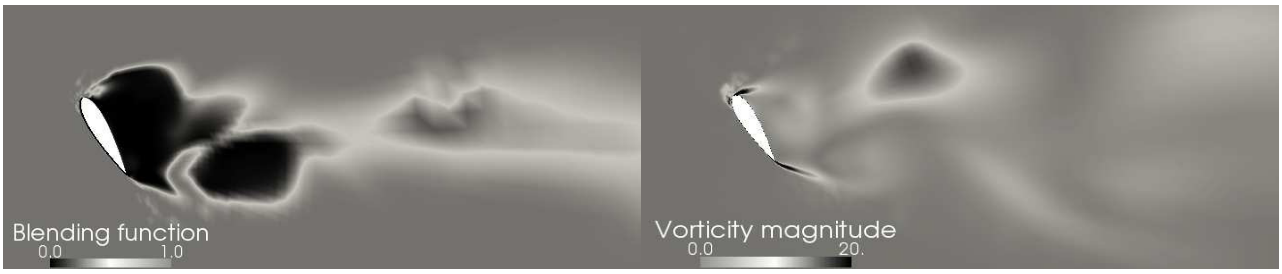


Figure: Evolution of vorticity magnitude and blending function for hybrid scheme shortly after initialization with results obtained by unsteady RANS

**Key words:** OpenFOAM, turbulence modelling, hybrid RANS-LES, DES, URANS, NACA0021, bluff body flow.

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