# Application of SST-based SLA-DDES formulation to turbomachinery flows

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In turbomachinery CFD simulations, Reynolds-Averaged Navier-Stokes (RANS) based approaches have a tendency to under predict the mixing of wakes, tip leakage flows and other secondary flow features formed in the endwall region, for example, corner separations in axial compressors, while at the same time over predicting their size. This has a dramatic impact on the performance predictions, which stems from poor prediction of spanwise profiles of total pressure or total temperature, where RANS typically yields more coherent features and much stronger undulations than experimental data. The hybrid RANS/LES methods (i.e. various DES formulations), with RANS modeling of the flow near the wall, and eddy-resolving simulation away from the wall, help to better represent the mixing in turbulent flows. Our previous work with DES models in a linear compressor cascade also showed that prediction of corner separation and thus loss profile can be greatly improved when unsteadiness outside of the boundary layer region is also resolved [1]. In high pressure turbine simulations with DES models, improvement in the mixing of the horseshoe vortex and the tip leakage vortex also leads to much improved loss profile predictions.

The original DES model suffers from pre-mature boundary layer separations. This is solved in the delayed-DES (or DDES) model, in which a sheltering function is added to prevent pre-mature separation. However, the DDES model also under predicts the mixing in the shear layers, particularly right close to the onset of the shear layer. This may be attributed to the lack of upstream turbulence fluctuation from a RANS boundary layer solution. However, due to the strong upstream turbulence kinetic energy, the RANS zone extends farther downstream than desired, due to the smaller turbulence length-scale as dictated in the DDES model formulation. The Kevin-Helmholtz instability does not start to develop until the RANS zone ends. The delayed transition to LES mode in the shear layer also leads to undesired mixing in the turbomachinery simulations. Specifically, the mixing in the wake of the blade and in the tip leakage flow is slow. The shear-layer-adapted (SLA) model within the framework of SA-DDES, aiming to unlock the Kevin-Helmholtz instability in the initial stage of the shear layer, addresses this issue [2]. SLA-DDES model uses the Vortex Tilting Measure (VTM) to detect the shear layer, and defines a new subgrid length scale that activates the LES model sooner. SLA-DDES model has also been reported to provide improvements in plane shear layer flows.

In this work, the SLA-DDES concept has been adopted in the context SST k-omega based DDES model. The model has been tested in canonical cases, and applied to turbomachinery flows. In Figure 1, the tip clearance flow in a compressor rotor DES simulation is shown. The isosurfaces of the Q criterion are plotted. In the original DDES model, the transition from RANS to LES is slow, and the RANS-like convection of the leakage flow vortices starting from the leading edge can be seen. In the SLA-DDES model, more eddies are resolved as the transition to LES is much faster. In the final paper, detailed comparison of the simulation from both models with the test data will be included.

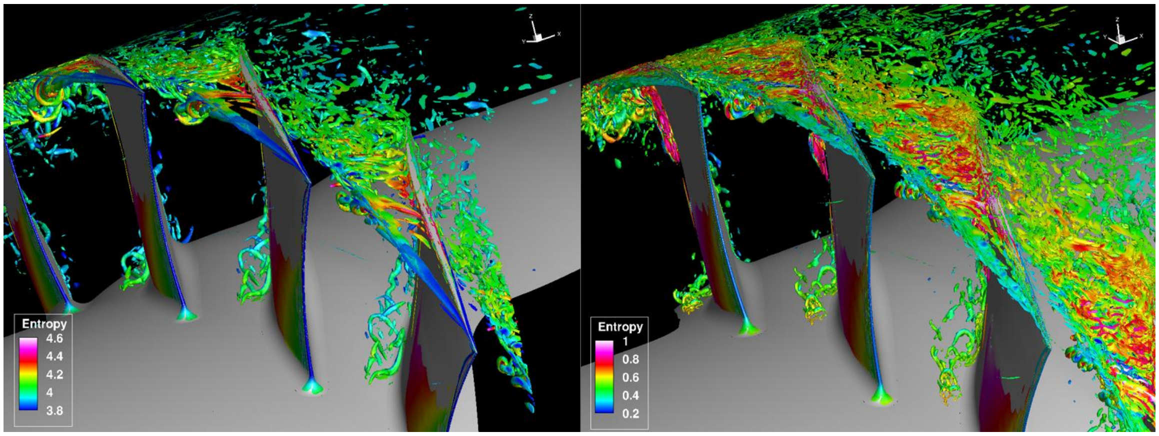


Figure 1. Tip clearance flow in a compressor rotor (Left: DDES model; Right: SLA-DDES model)

## References:

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