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Session:

Assessment of Delayed Detached-Eddy Simulation of Dynamic Stall on a Rotor

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Dynamic stall is an unsteady, three-dimensional flow phenomenon that occurs on helicopters in high-speed or manoeuvring flight and limits their flight envelope. As the rotor blade is temporarily pitched beyond its static stall angle, vortices evolve at the leading edge, convect downstream and are shed into the wake, leaving the flow massively separated for a large portion of the azimuth.

The ever increasing computational resources enable spatial and temporal resolutions fine enough to reasonably carry out delayed detached-eddy simulations (DDES) [1] of dynamic stall. Recently, Letzgus et al. [2] investigated the phenomenon on a model rotor with cyclic pitch control using the block-structured finite-volume solver FLOWer by DLR that was upgraded with modern DES capabilities by IAG [3]. After the primary dynamic stall event, when the flow is completely separated, DDES results agree significantly better with experimental particle image velocimetry (PIV) and surface pressure data [4] than URANS results.

However, during the complex transition from fully attached flow to trailing edge separation to leading edge stall – all occurring during a short phase near the end of the upstroke – the DDES seems to suffer from modeled-stress depletion leading to grid-induced separation (GIS) – see Fig. 1. This severely alters the key characteristic of dynamic stall, the overshoot of lift and nose-down pitching moment, and thus questions the applicability of the numerical approach. As also shown before, for example by Ashton [5], a too fine grid can easily corrupt the boundary-layer shielding function f_d. Increasing the empirical constant C_{d1} has a strong influence and can to some extent suppress premature moment stall – see Fig. 2. However, a thorough recalibration is inevitable.

In the final paper, the DDES approach to simulate dynamic stall on a rotor using a high-resolution grid is assessed. In detail, the presence of GIS is demonstrated and possible remedies, such as increasing C_{d1}, but also applying alternative shielding methods currently developed and investigated at IAG, are evaluated.

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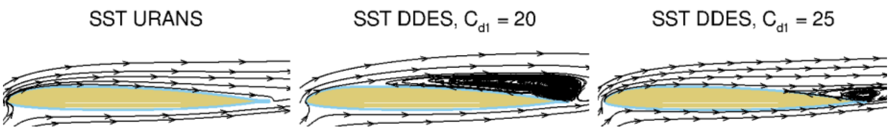

Fig. 1 In-plane streamlines at 77 % rotor radius at t/T = 0.43 (upstroke) indicate grid-induced trailing edge separation with DDES and influence of empirical constant C_{d1}.

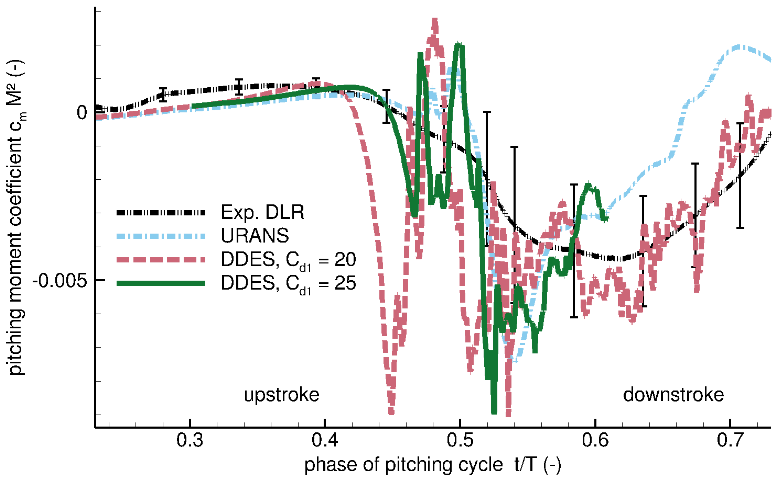

Fig. 2 Influence of empirical constant C_{d1} of SST-DDES on local pitching moment during dynamic stall on a model rotor blade.

References

[1] Gritskevich, M. S., Garbaruk, A. V., and Menter, F. R., "Fine-tuning of DDES and IDDES formulations to the k-ω Shear Stress Transport model," Progress in Flight Physics, Vol. 5, pp. 23-42, 2013.

[2] Weihing, P., Letzgus, J., Bangga, G., Lutz, T., Krämer, E. "Hybrid RANS/LES capabilities of the flow solver FLOWer - application to flow around wind turbines," 6th Symposium on Hybrid RANS-LES Methods, Strasbourg, September 26-28, 2016.

[3] Letzgus, J., Gardner, A. D., Schwermer, T., Keßler, M. and Krämer, E., "Numerical investigations of Dynamic Stall on a Rotor with Cyclic Pitch Control," 43rd European Rotorcraft Forum, Milan, September 12-15, 2017.

[4] Schwermer, T., Gardner, A. D., and Raffel, M., "Dynamic Stall Experiments on a Rotor with High Cyclic Setting in Axial Inflow," 73rd Annual Forum of the American Helicopter Society, Fort Worth, TX, May 9-11, 2017.

[5] Ashton, N., "Recalibrating Detached-Eddy Simulation to eliminate modelled-stress depletion," Paper 2017-4281, 23rd AIAA Computational Fluid Dynamics Conference, Denver, CO, June 5-9, 2017.

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[2] Second reference