SCALE RESOLVING SIMULATION OF NACELLE / LOWER-WING INTERFERENCES NEAR HIGH SPEED STALL CONDITIONS

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Abstract
Over the past years, the designs of jet engines for transport aircraft tend to grow in size and fan diameter, since the propulsion efficiency of turbofans increases with the bypass ratio. These large engines need to be closely coupled with the wing due to spacing constraints resulting in strong interference effects between the flow around the engine nacelle and the wing [1]. Especially for transonic flows at the borders of the flight envelope, these flow interferences are not yet understood, and they are difficult to predict with conventional statistical turbulence models. For this reason, the present work, which is part of the DFG-FOR2895 project on “High-speed stall”, focuses on improving and validating a turbulence resolving method for this kind of flow.

Although a direct numerical simulation (DNS) or a large eddy simulation (LES) of the entire airframe configuration would enable detailed analysis of these interference problems, such simulation approaches are too demanding with respect to grid size and corresponding computational resources. Thus, a hybrid simulation approach which models the turbulence of the inner boundary layer by an efficient Reynolds-averaged Navier-Stokes (RANS) model and resolves the remaining area with wall-modelled LES is selected for this flow problem.
Since the nacelle-airframe configuration exhibits several corner flow regions (e.g. between pylon and wing in Fig. 1) associated with flow separations and longitudinal vortices, a RANS turbulence model which accounts for turbulence anisotropy is required. Consequently, to meet the different requirements of the numerical simulation of such a complex configuration, a hybrid RANS-LES method based on a Reynolds stress model (RSM) is applied.
Since such approaches are limited and insufficiently validated in literature, a novel hybridization approach between RSM background model and LES model was developed and validated for different canonical test cases [2]. Furthermore, a comparable simulation approach was successfully applied to a nacelle-airframe configuration, in order to analyze a local transonic shock front at the outer nacelle surface [3].

In order to study the transonic interference around the engine installation, the target region for the newly developed approach is located at the lower wing area between fuselage and pylon.

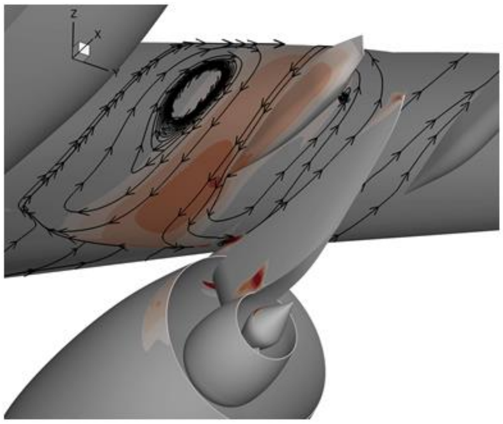

Figure 1 [4]. Bottom view of nacelle-pylon-wing configuration with surface pressure distribution.

In this region, which extends over 20% of the entire half span, a system of transonic shocks appears. For this challenging simulation setup, a mesh of 800 million grid cells has been constructed fulfilling local wall modelled LES refinement criteria in the region interest.

The final presentation will provide an overview of the method development and studies conducted on nacelle-airframe interference within the DFG-FOR2895 project. Besides, it will present simulation results with a focus on transonic shock dynamics, as well as an analysis of the mutual interactions within the shock system.

References

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[4] **Herr, M., Spinner, S., Probst, A., Rudnik R., & Radespiel R.** (2023). Embedded WMLES of transonic buffet on a nacelle-aircraft configuration. AIAA SciTech Forum, 23–27 January 2023, National Harbor, MD, AIAA Paper 2023-0246.