

APPLICATION OF A SYNTHETIC TURBULENCE GENERATOR IN AIRCRAFT AND TURBOMACHINERY AERODYNAMICS

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Abstract

Methods for generating synthetic turbulent fluctuations in numerical flow simulations have gained increasing attention over the past years [1]. Such methods usually rely on statistical input data of turbulent flow, such as the Reynolds stress tensor and integral length scales, which serve as target quantities for the computed time-resolved fluctuations. Typically, random quantities are involved in the generation process in order to mimic the quasi-stochastic behavior of turbulence. Applications of synthetic turbulence generators (STG) range from initializing whole turbulent flow fields to posing turbulent boundary conditions in LES simulations to generating acoustic sources for the computation of sound propagation [2]. The choice of the STG method may depend on the specific requirements of the application, e.g. divergence-free properties or exact reproduction of target Reynolds stress.

In the DLR project ADaMant, however, one specific method, the NTS-STG [1], has been applied in two rather different fields with different underlying mechanisms in mind: on the one hand, in order to allow for local wall-modelled LES (WM-LES) on the surface of e.g. an aircraft wing or engine nacelle, the STG is applied inside the fully turbulent boundary layer to ensure quick transition from RANS to WM-LES. This approach, sketched in Figure 1 (top), involves forcing and reference regions surrounding the (prescribed) RANS/WM-LES interface, automatic extraction of statistical STG-input data and injection of the STG fluctuations via volumetric source terms [3]. The implementation in the DLR-TAU solver has recently been extended to more general 3D geometries, as will be demonstrated for different flow cases with increasing complexity. Besides, by combining this approach with wall functions, significant steps towards the feasibility of local WM-LES at higher Reynolds numbers are taken.

On the other hand, the STG is used to provide realistic ambient turbulence levels in the freestream of turbomachine components, in order to simulate transitional (laminar/turbulent) flow. To this end, the fluctuations from STG are injected via the inflow boundary condition of the internal flow domain, see Figure 1 (bottom). In the present work, the interaction of resolved inflow turbulence with a seamless hybrid RANS/LES method (Delayed DES), which is coupled with a transition transport model [4], is assessed. To

analyze this, the compressor cascade V103 will be considered. For the investigated operating point, both transition types (bypass and separation-induced transition) occur, which will be analyzed in detail. Both types of applications of the NTS-STG will be put in a common context, highlighting their specific requirements on the STG as well as current deficiencies and potential improvements.

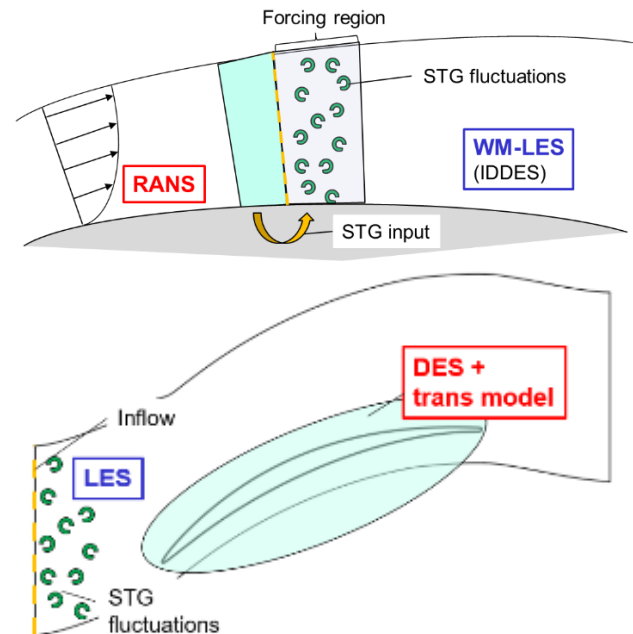


Figure 1 STG applied inside the boundary layer (top) and at the inflow for ambient turbulence (bottom).

References

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