

# Large-eddy simulation of aeroacoustics

## Numerical investigation of acoustic radiation issuing from supersonic boundary layer with porous riblets

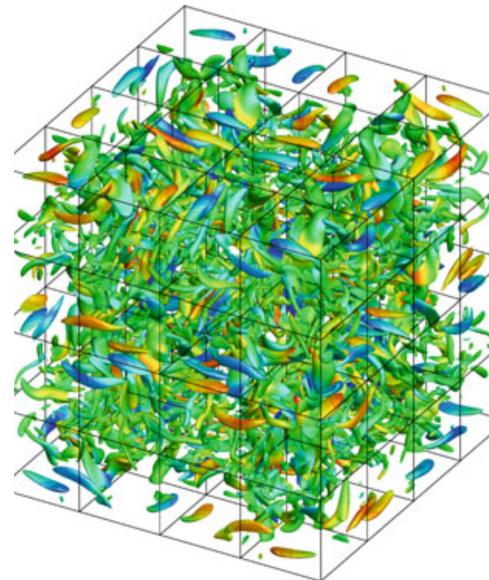
**J. Wu, R.A.D. Akkermans, Institute of Fluid Mechanics, Technical University of Braunschweig**

### In Short

- Overset-LES for Hybrid RANS/LES simulations
- Acoustic simulation of supersonic turbulent boundary layers
- Acoustic radiation control using porous and riblets wall

The proposed research aims to formulate a more holistic investigation of noise generation issuing from supersonic turbulent boundary layer with porous riblets by using a novel hybrid RANS/LES method with the function of acoustic wave prediction, i.e. the so-called Overset-Large Eddy Simulation (LES). Statistical turbulence characterization both inside and outside the supersonic turbulent boundary layer induced by the porous riblets structure will be examined with an emphasis on the correlation between the pressure fluctuation underneath the boundary layer and the radiated acoustic waves into the freestream. Additionally, the influence of the relevant sensitivity parameters, such as the groove aspect ratio, porosity, pore's aspect ratio, freestream Mach number and Reynolds number are comprehensively investigated and the corresponding results will be both qualitatively and quantitatively analyzed and discussed. Through this study it is expected to obtain a better understanding of the mechanism of noise generation from supersonic turbulent boundary layer with porous riblets and provide a promising solution for the acoustic wave mitigation in supersonic or hypersonic wind tunnels. In order to fulfill the scope of the current proposal, a systematic numerical investigation of the acoustic generation and propagation issuing from supersonic boundary layer with porous riblets will be carried out under this framework using the Overset LES tool in this proposal[1,2]. This Overset LES is developed based on the DLR CAA-code PIANO (Perturbation Investigation of Aerodynamic NOise) that solves appropriate acoustic perturbation equations on top of a time-averaged background flow[3]. The Overset LES solves the perturbation equations on the basis of a time-averaged background flow and captures the sound source term giving rise to the acoustic radiation; simultaneously, it predicts the acoustic propagation using the full

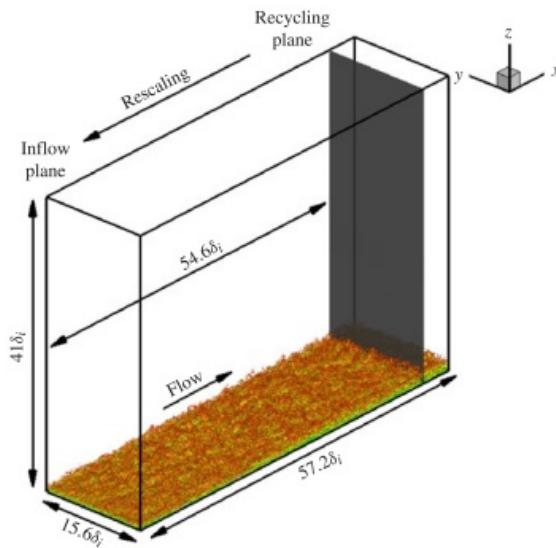
Navier-Stokes equations in disturbance form. In nature the Overset LES is a hybrid RANS/LES solver and equipped with high-order, low-dispersive and low-dissipative numerical schemes[4], which allows for the accurate resolution of high wave number components. The viscous-PIANO code has been applied to generic test cases (e.g. decaying turbulence initialized with Taylor-Green vortex flow, see Figure 1). The porous material will be modeled with a volume-averaged approach suggested by Breugem et al[5,6], and this model has been implemented in the Overset-LES code and is currently being applied to NACA0012 trailing-edge simulations.



**Figure 1:** Snapshot of decaying turbulence initialized with Taylor-Green Vortices[1].

The simulation of acoustic radiation due to supersonic turbulent boundary layer based on a flat plate will be conducted first using a novel hybrid RANS/LES approach. The flow conditions will follow that used by Duan et.al[7] in a DNS simulation setup(as seen in Figure 2 ), thus a validation of the results is available afterwards. Secondly, sole riblets structure with recommend size by Duan and Choudhari[8] will be implemented on the flat plate, and the turbulence statistics both inside and outside of the supersonic boundary layer will be compared for the above two wall models. Moreover, the radiated acoustic wave properties, e.g., the wave front and the convective velocity, will be compared. Thirdly, porous materials will be employed together with the riblets structure, and the influence of porous material

to the resultant turbulent boundary layer and acoustic field will be both qualitatively and quantitatively examined.



**Figure 2:** Numerical Schlieren image based on instantaneous flow field at Mach 2.5[7].

The properties of the porous riblets and also the freestream conditions are considered to have a large impact of the turbulence evolution within the boundary layer, and further alter the pressure fluctuations propagating into the freestream. In the first step, the influence of the porous riblets? properties, such as the groove size, aspect ratio, porosity and open ratio, will be systematically surveyed. Both spatial-spatial and spatial-temporal cross-correlations of the pressure fluctuations underneath and outside of the turbulent boundary layers will be performed. The association of the porous riblets? property to the acoustic wave radiation behavior will be established and an optimized porous riblet will be defined based on the parameter sensitivity study. Secondly, the influence of the freestream conditions, i.e., Mach number and Reynolds number, will be studied.

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- [8] Duan, L., and Choudhari, M. M. "Direct Numerical Simulations of High-Speed Turbulent Boundary Layers over Riblets," Aerospace Sciences Meeting. 2014, AIAA Paper 2014-0934.

## WWW

<https://www.tu-braunschweig.de/ism>

## More Information

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