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Mitigation of landing gear noise using porous fairings

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Motivation

Reducing noise generated by landing gears during take-off and approach is one of the major challenges in modern aircraft design requiring new disruptive noise mitigation concepts. Recently, the installation of porous trailing edges at wings showed favorable noise mitigation properties. In the present study, different upstream installed porous fairings are accessed by numerical means. Objective is to understand their mode of noise mitigation to draw conclusions on effective usage of porous fairings.

Numerical method and implementation

Cumulant lattice Boltzmann method

The Boltzmann equation (eq. (1)) describes the evolution in time t of the momentum distribution function $f(\underline{x}, \underline{v}, t)$. This function represents the density of particles at the position $\underline{x}$ and time t with a velocity $\underline{v}$. Discretization yields the lattice Boltzmann equation (eq. (2)).

$$\frac{\partial f}{\partial t} + \underline{v} \cdot \nabla f = \Omega(f) \tag{1}$$

$$f_i(\underline{x} + \underline{c}_i \Delta t, t + \Delta t) = f_i^*(\underline{x}, t) = f_i(\underline{x}, t) + \Omega_i(f) \tag{2}$$

The collision operator Ω accounts for the effect of momentum exchange of particles colliding with each other. It relaxes the distribution towards a Maxwell equilibrium distribution function. Here, the collision is performed in a cumulant space (eq. (4)). Therefore, f is transformed into countable cumulants c (eq. (3)) [1].

$$c_{\alpha\beta\gamma} := c^{-\alpha-\beta-\gamma} \frac{\partial^\alpha \partial^\beta \partial^\gamma}{\partial \Xi_i^\alpha \partial \Xi_j^\beta \partial \Xi_k^\gamma} \ln(F(\Xi)) \Big|_{\underline{\Xi}=\underline{0}} \tag{3}$$

$$c^*_{\alpha\beta\gamma} = c_{\alpha\beta\gamma} + \omega_{\alpha\beta\gamma}[c^{eq}_{\alpha\beta\gamma} - c_{\alpha\beta\gamma}] \tag{4}$$

Acceleration using GPUs

With the cumulant LB method a well parallizable numerical scheme for high Reynolds number flow is obtained. The implementation follows a hardware-agnostic approach for homogeneous and heterogeneous many-core platforms. It is based on MPI and higher-level parallelism features introduced by the C++17 Standard, which are realized in the NVIDIA HPC SDK. A strong scaling is shown in Fig. 1.

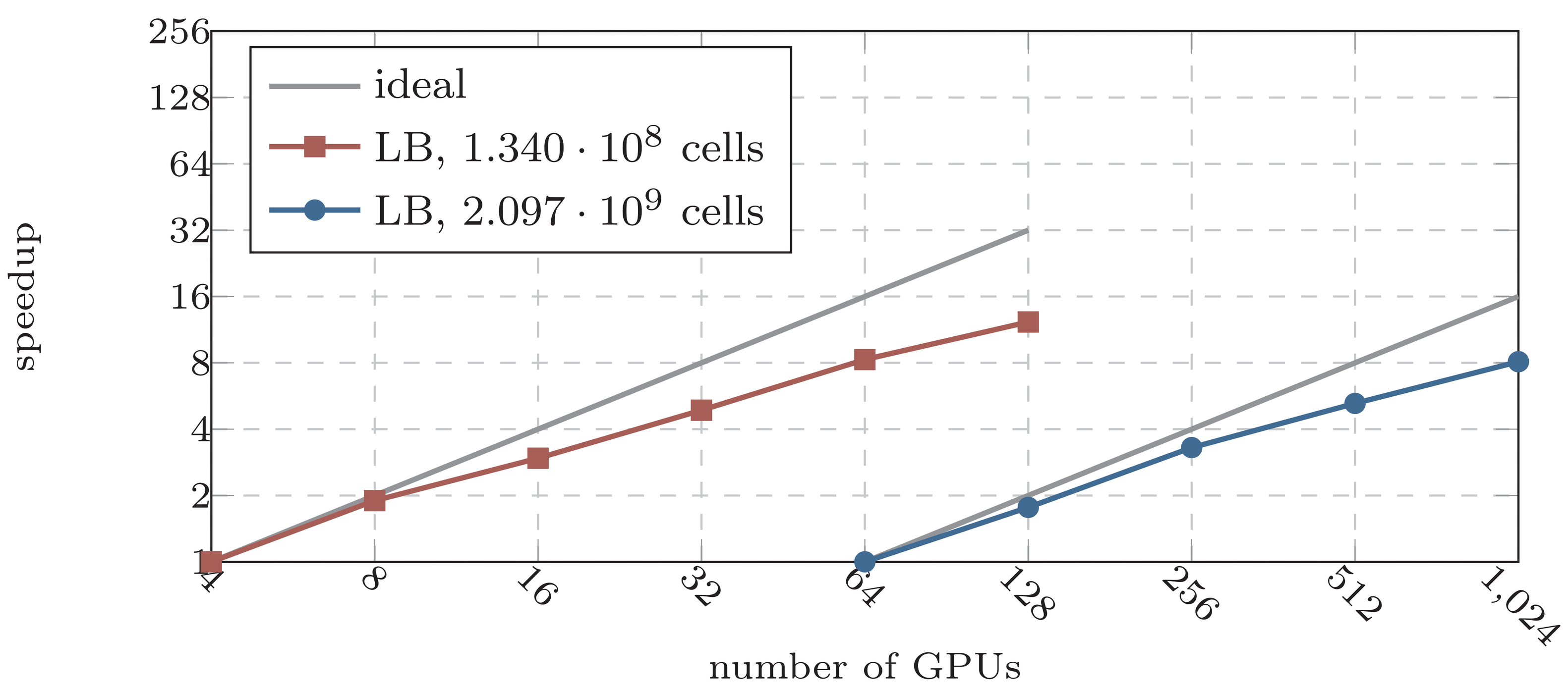

Figure 1: Strong scaling on JUWELS Booster for a LB-CFD simulation in three space dimensions accelerated by NVIDIA A100 GPUs.

Acknowledgements

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References

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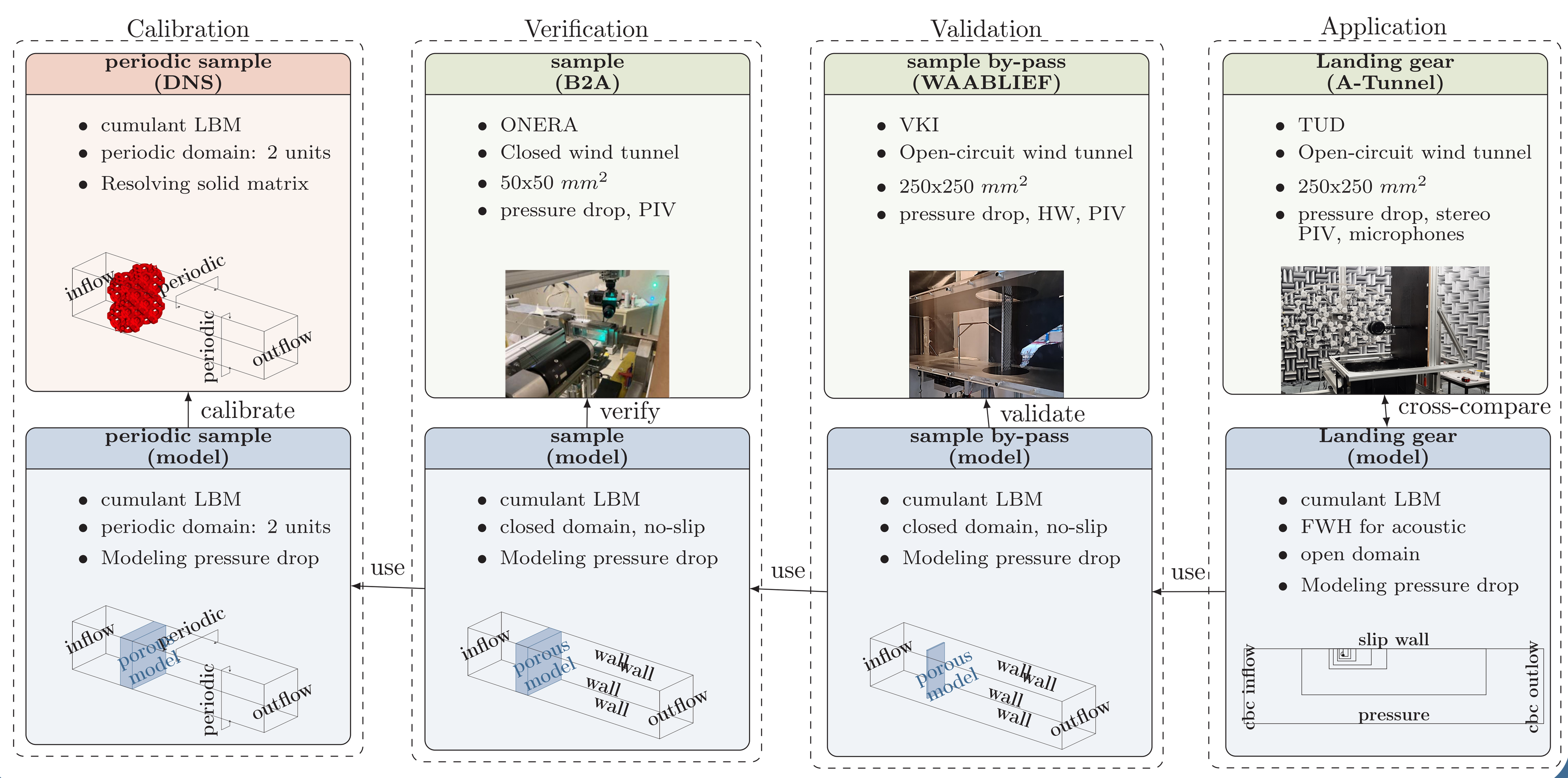
[3] M. Gondrum, S. Satcunanathan, A. Niemöller, M. Meinke, and W. Schröder. A Direct-Hybrid CFD/CAA Method based on Lattice Boltzmann and Acoustic Perturbation Equations. *Acta Acust.*, 6, 2022. (Under review).

Workflow



DNS of flow through a porous material

A flow through a periodic section of the *diamond lattice structure* is fully resolved at different bulk velocities to characterize the properties of the material. The obtained data is used to calibrate a porous model applied in the landing gear simulation with installed fairing.

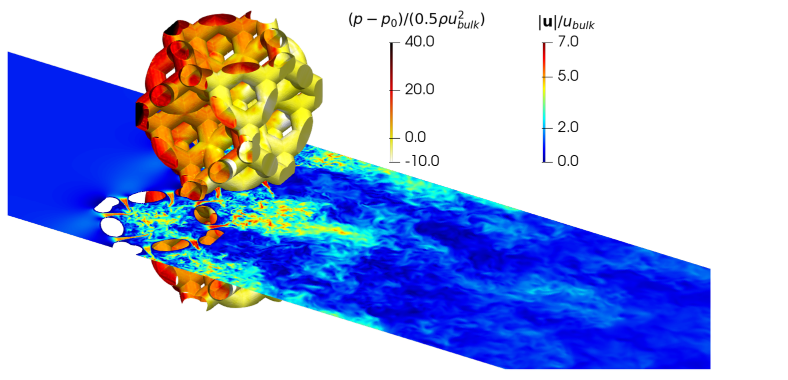


Figure 2: Flow field through the diamond lattice structure.

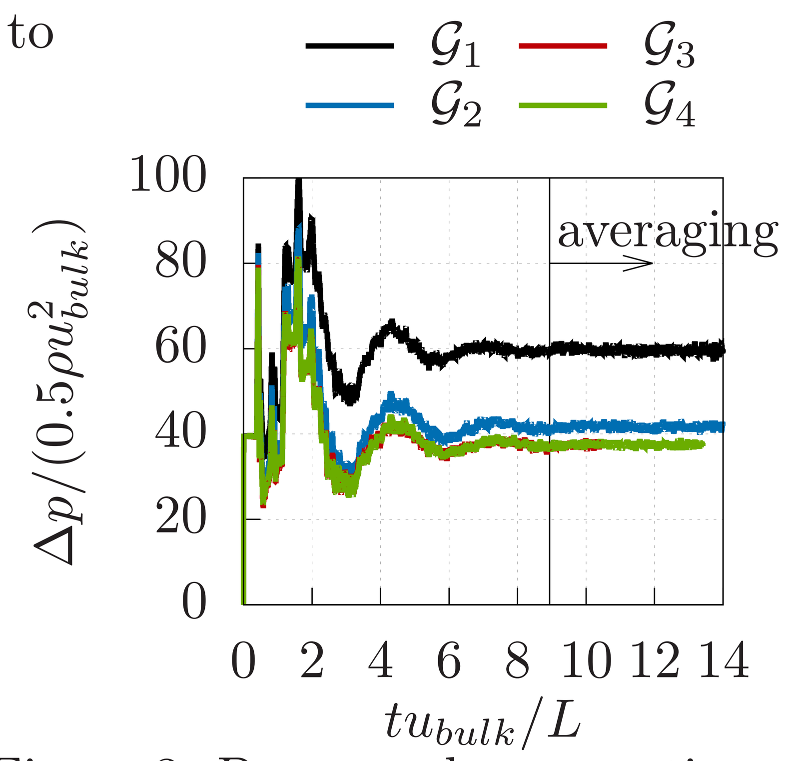


Figure 3: Pressure drop over time of different grids with increasing resolutions.

Landing gear with upstream installed fairing

A simplified two-wheel nose landing gear model with a 1:7 real scale is investigated at a freestream Mach number $M_\infty = 0.1$ and a wheel based Reynolds number of $Re_D = 346,306$ [2]. The noise mitigation properties of different kind of porous fairings are subject of this study.

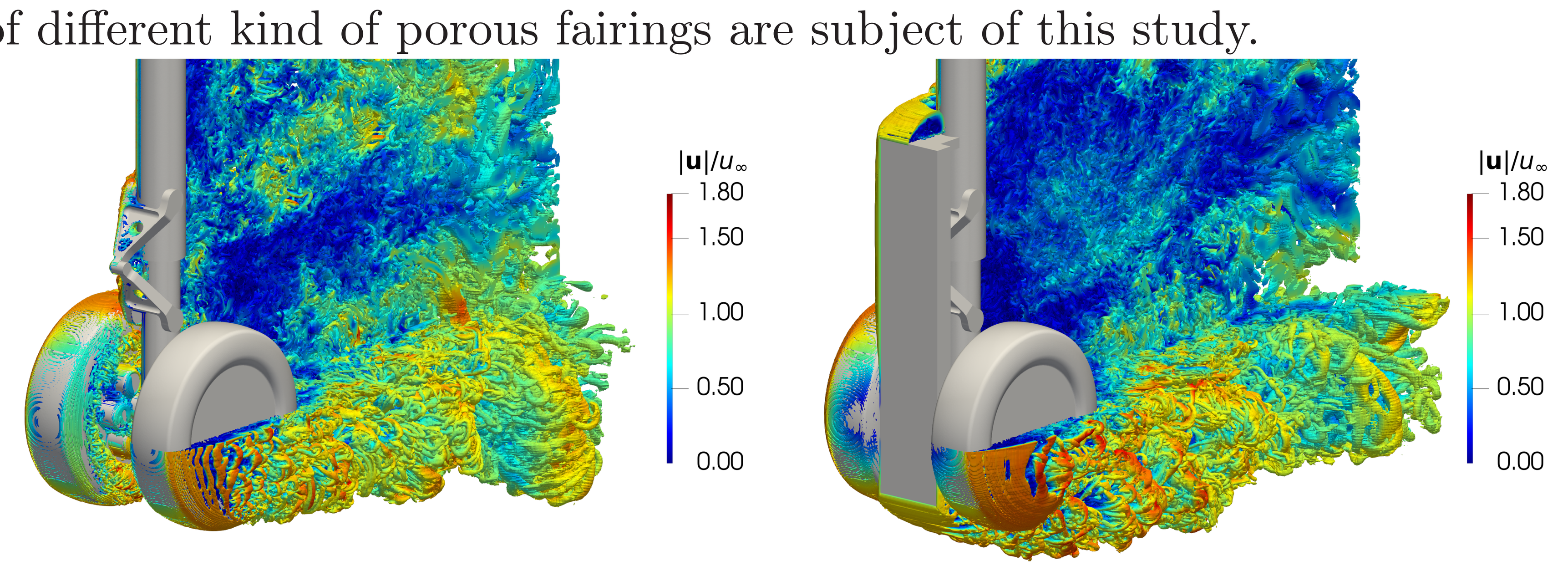


Figure 4: Velocity magnitude on isosurfaces of Q-Criterion for the baseline (left) and baseline with a fairing (right) landing gear configuration.

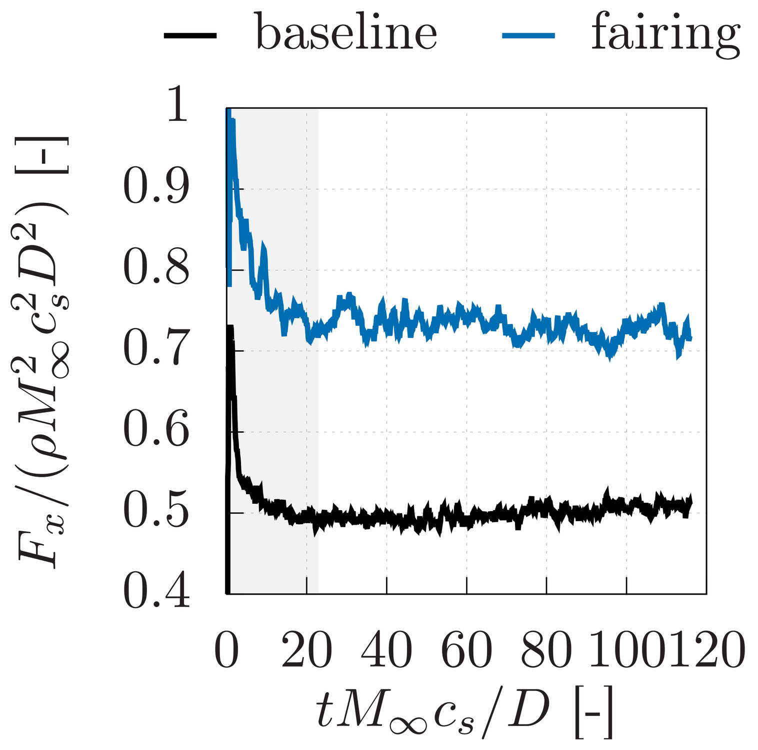


Figure 5: Temporal evolution of the aerodynamic drag force acting on the baseline and the baseline with fairing configuration.

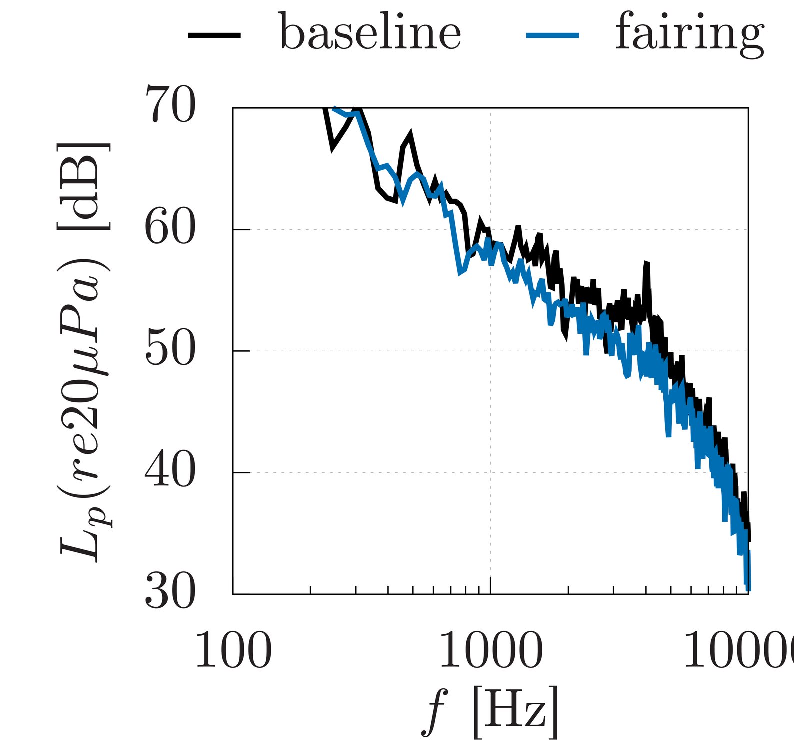


Figure 6: Sound pressure level generated by the baseline and the baseline with fairing configuration calculated at a flyover position in a distance of nine wheel diameters.