Mitteilung

Projektgruppe / Fachkreis: Technische Strömungen

Large Eddy Simulation of the flow around an idealized high-speed train

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For the optimization of modern high-speed trains it is essential to fully understand the instantaneous and time-averaged flow around the train body. Recent numerical studies are mostly based on solutions of the Reynolds Averaged Navier Stokes (RANS) equations to investigate the development of the flow. For the study presented here however Large Eddy Simulation (LES) has been performed to obtain more details regarding the time-dependent aerodynamic loads and more reliable results in general. Since the front of a train is subjected to the largest forces[1], the focus of this study was laid on the flow around the train's nose. Therefore a simplified model of a high-speed train has been developed for the first simulations. Also geometrically more complex train models will be considered. A further simplification of the set-up was to investigate a low Reynolds number flow in order to lower the already quite high computational costs that the application of the LES technique usually implies. Typical Reynolds numbers for investigations of the flow around a modern high-speed train are of the order of 10-15 Mio, based on the free stream velocity and the standard train width (d=3m). This study was conducted with a Reynolds number of 280000, also based on the free stream velocity and, since the model is a scaled version of the original train, the scaled train width (d=3/25m). Simulations have been performed without and with a side-wind leading an angle of attack of 30° to examine cross-wind effects. For subgrid-scale modeling the Smagorinsky model[2] in combination with van Driest damping were used. The simulations have been carried out with a second order central differencing method on an unstructured grid with more than 9 Mio (no side-wind, 0°) and 15 Mio (angle of attack: 30°) cells.

In Figure 1(a) and (b) the instantaneous velocity field in streamwise direction is displayed. It shows the turbulent nature of the flow around this bluff body, especially in the wake of the train's head and below the undercarriage.

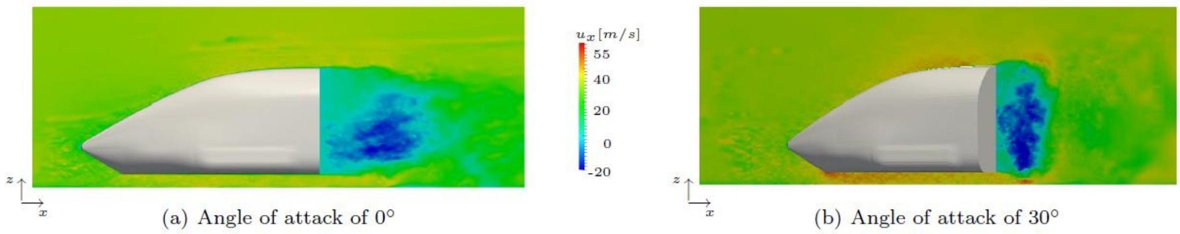
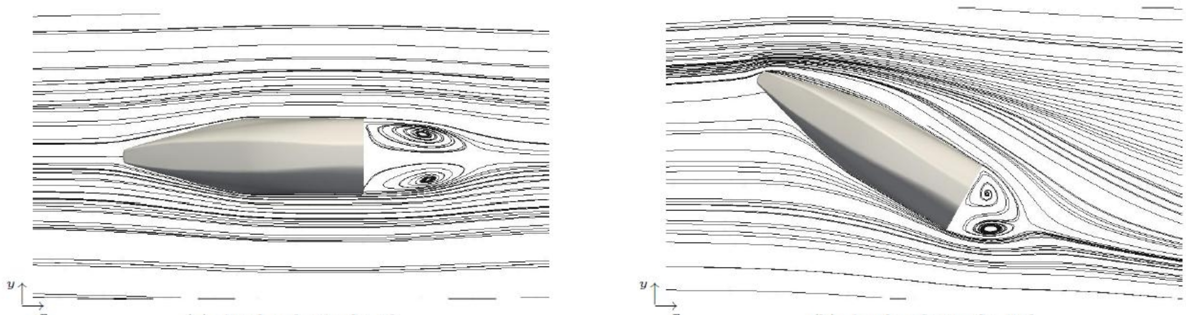


Figure 1: Instantaneous velocity field around the simplified train model in streamwise direction

1 Gawthorpe, R. G., (1978), Aerodynamics of Trains in the Open Air, ImechE Railway Engineer International
2 Smagorinsky, J., (1963), General Circulation Experiments with the Primitive Equations, Mon. Weath. Rev., Vol 91, pp. 99-164

The time-averaged flow behaviour around the train's head can be seen in Figure 2(a) and (b) where the streamlines projected onto the z-plane without and with side-wind component at a 30° angle of attack are presented. In Figure 2(a) two almost symmetrical vortices can be observed in the wake of the train's head. This is characteristic for a bluff body flow. For the 30° angle of attack there is a shift in the two vortices in the wake, since the flow around the body is no longer symmetrical.



(a) Angle of attack: 0° (b) Angle of attack: 30°

Figure 2: Time-averaged streamlines projected onto the z-plane for different angles of attack of the flow around the simplified train model

References

[1] Gawthorpe, R. G., (1978), Aerodynamics of Trains in the Open Air, IMechE Railway Engineer International
[2] Smagorinsky, J., (1963), General Circulation Experiments with the Primitive Equations, Mon. Weath. Rev., vol. 91, pp. 99-164