Computational Modeling of the Flow Past Stationary and Rotating Road Vehicle Wheel

Researchers
Alejandro Correa Pineda

Principal Investigator
Lukas Kutej

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Clusters
Lichtenberg Cluster Darmstadt

Institute
Fachgebiet Strömungslehre und Aerodynamik

University
Technische Universität Darmstadt

Introduction

In this bachelor thesis an investigation of a flow with high Reynolds number (Re=1.4x10 5) past stationary and rotating circular cylinder is performed. URANS (Unsteady Reynolds Averaged Navier-Stokes), PANS (Partially-Averaged Navier-Stokes) and VLES (Very Large Eddy Simulation) methods, where a k-ε-ζ-f turbulence model is used, are performed. The object is to compare results of drag, lift, and pressure coefficients and velocity profiles, with experimental data of Cantwell & Coles (1983) and with numerical results of Breuer (2000) and so validates used PANS and VLES methods. The investigation is carried out to establish an influence of a CFL number and a mesh on the results.

Methods

The circular cylinder has a diameter of 0.0426m, which is the most used scale in many calculations. Afterwards, an investigation of a flow with high Reynolds number (Re=3x10 5) around an isolated wheel with ground contact is performed and computed by the same methods aforementioned. Two cases are considered: a nonrotating wheel on a stationary ground and a rotating wheel on a moving ground; the wheel has a diameter of 0.416m, which is approximately ten times bigger than the cylinder. The geometry which was chosen is a Fackrell's wheel B with wheel shoulder shape 2 (1972). The object is to compare the results of lift, drag coefficients, pressure distribution, and velocity fields, with experimental data of Fackrell (1972) to show that the chosen URANS, PANS, VLES methods are suitable for such kind of cases with high Reynolds number. The results have an application to design of road vehicles. The section of the cylinder demonstrates deficits of simple URANS simulation with k-ε-ζ-f model. The turbulence is unresolved, there are modeled only the biggest structures. The other two eddy resolving methods PANS and VLES resolve the turbulence in important parts of the computational domain what brings significant improvement to capture the flow structures properly and so get better results for all important flow variables. As regards to the remaining results, i.e. the separation point, drag coefficient, lift coefficient, and pressure coefficient, are in concert with the experimental data with Aoki (2001) and Cantwell and Coles (1983) for both the stationary and rotating cases. If the refinement of the mesh is small, both methods are close to achieve the same results. This does not happen with URANS, as shown by its performance being completely different from that of PANS and VLES. The final filter parameter fk demonstrates differences between PANS and VLES. In the case of PANS there are some areas on the cylinder surface and its boundary layer where the PANS does not resolve the turbulence and use more the URANS k-ε-ζ-f unresolved part. On the other hand VLES method resolves the turbulence on this important cylinder surface and its boundary layer. In this fact VLES deliver more accurate values of variables which depend on properly capturing of behavior in near wall region. The difference in the fk which was observed is created by different approach by estimation of resolved and unresolved turbulent kinetic energy.

Results

The velocity profiles results for nonrotating case predict differences with the experimental data but this differences will not change the final results or conclusions. The averaged kinetic energy plots demonstrate that a big recirculation area has a small kinetic energy and vice versa. The results show that the mesh is coarse enough to benefit from the hybrid approach VLES because the relation with fk is adequate. The y+ values on the cylinder are accurate enough to properly resolve the viscous sublayer.

Discussion

The section of the wheel demonstrates that in order to see the structures of the flow, it can be calculated with any of the mentioned methods, but to get a detail of these structures, it is better to use a method that resolve the eddy structures, for example PANS or VLES. The same wind tunnel domain than Fackrell’s (1974) was taken in order to preserve the blockage effect as it is a small domain. The calculations show that the mesh is not fine enough because the relation with fk is not adequate. More proofs are needed to totally validate the VLES method, but with the available information, a VLES with implemented k-ε-ζ-f model is a good way to calculate critical Reynolds numbers.

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