Final Master Thesis Project
Evaluating the EWI Wind Tunnel Performance

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High wind speeds during stormy weather have created notoriously dangerous situations in an area close to the EWI/EEMCS building. The vortex created downstream the building induces high wind speeds in the vicinity of the intersection of the Drebbelweg and the Mekelweg. The type of flow considered can be described by the incompressible Navier-Stokes equations complemented with an appropriate turbulence model. The objective of this project is to gain a basic understanding of the modeling of turbulent flow, to perform turbulent flow computations, to implement an established two-equation model such as the k-ϵ turbulence model into an existing open-source laminar flow solver, to perform numerical simulations of some turbulent flows, and possibly to find strategies to reduce the undesirable wind tunnel effect of the EWI building.

In a first stage of the project the prospective student will perform a literature study on the modeling of incompressible turbulent flows. To keep the numerical computations tractable, one typically resorts to some kind of averaging procedure over turbulent length scales resulting in the so-called Reynolds-Averaged Navier-Stokes Equations (RANS) [1]. The information lost during the averaging is compensated for by complementing the RANS equations with closure relations for turbulence quantities. A large family of turbulence models exists in the literature. In this project we foresee the possibility to compare some of the most popular of these models, among which the widely accepted$k$-ϵ model involving the kinetic energy k and the dissipation rate ϵ. The literature study will result in a concise definition of the k-ϵ turbulence model that includes the convection-diffusion-reaction equations for the k and ϵ, the boundary conditions and the initial conditions for the non-linear solution procedure. The literature study will also result in the definition of a set of model problems that will be used in the second stage of the projects to verify the implementation and to validate the parameters in the turbulence model. This set may include the flow over a backward facing step, the flow across an object placed in a channel and a simplified representation of the EWI wind tunnel. A selection of a turbulent flow (either commercial or public) solvers to be used in the project will also be made.

In the second stage of the project the student will be given the opportunity to gain hands-on experience with an existing turbulent flow solver to solve the test cases defined in the first stage for various flow regimes, model parameters and turbulence models. Results of the simulations will be compared with results published in the literature and possibly with results of direct numerical simulations. We foresee the possibility to make use of an open-source simulation suite that provides modules for laminar and turbulent flow. In this way the student becomes familiar with the general code structure that will simplify the implementation work in the third stage.

In the third stage of the project the student will implement an k-ϵ turbulence model within an existing finite element flow solver. Depending on the programming skills of the student, a selection between different codes written in C++, Fortran or Python can be made. Aspects such as the meshing to capture the boundary layers, the discretization and the (non) linear solution procedure will be looked into.

In the fourth stage of the project the student will be able to explore personal interests within the framework of this proposal. One option consists of gradually increasing the complexity of the EWI wind tunnel model and to explore possibilities to reduce the formation of undesired wakes.

References

[1] H. K. Versteeg and W. Malalaseka. *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*. Pearson, second edition, 2007.