Professur für Hydromechanik
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Master's Thesis (30 ECTS)

Development of a boundary layer equations solver

Language: German or English

Motivation

- In high Reynolds number flow around bluff bodies, a thin boundary layer develops where the flow impinges on the body. This boundary layer is laminar and cannot be modelled using conventional turbulent wall models based on the logarithmic law of the wall. Hence, to simulate such flows, we currently need to resolve the flow very close to the wall, leading to extreme resolution requirements.

- A way to circumvent this limitation could be to represent the near wall flow using the integral boundary layer equations (Schlichting & Gersten, 2006) and to couple the boundary layer equations to the outer flow. In this approach, the velocity profile in the boundary layer is represented for example as a polynomial in terms of the velocity of the outer flow and a boundary layer thickness. This leads to a 2-dimensional system of equations on the surface of the body that is coupled to the outer flow. The result will be somewhat similar to what is described in Yang *et al.* (2015).

- Our in-house CFD code MGLET (Manhart *et al.*, 2001; Peller, 2010; Sakai *et al.*, 2019) that we develop jointly with our industrial partner KMT solves the Navier-Stokes equations using a second-order Finite Volume scheme on Cartesian grids. Complex geometries are treated by a cut-cell immersed boundary method (Dröge & Verstappen, 2005). MGLET is an MPI parallel code written in Fortran and is used on the latest supercomputers.

Objective of the thesis

- The goal of the thesis would be to implement an algorithm into our code MGLET that can solve the boundary layer equations on the surface of the immersed bodies.

- Once that works, one could try to implement a bidirectional coupling of the boundary layer equations to the flow solver.

Tasks

1. Literature survey of strategies on how to solve the integral boundary layer equations if the outer flow is known (a brief review is given by van Garrel (2004)) and decision for a scheme. (3 weeks)
2. Implement a solver for the integral boundary layer equations in MGLET based on the cut-cell method (Dröge & Verstappen, 2005):
   (a) Get acquainted with MGLET. *(3 weeks)*
   (b) Create a surface mesh data structure that contains the neighbourhood relations of the intersected cells. Currently, only these neighbourhood relations are unknown. On this mesh the boundary layer equations will be solved. *(4 weeks)*
   (c) Implement a discretisation of the integral boundary layer equations on this surface mesh and verify it. Possible benchmark cases are solutions from boundary layer theory for flow around an airfoil or flow around a cylinder *(10 weeks)*
3. Writing of the thesis *(6 weeks)*

Recommended literature

- book of Schlichting & Gersten (2006), you can download it via the TUM library
- review of van Garrel (2004)

Further notes

The thesis would be co-supervised by our industrial partner KMT (`http://www.km-turbulenz.de/`). There would be the possibility of a student job at KMT.

Requirements

The thesis work will require programming in modern Fortran.

Required skills:

- good programming skills in MATLAB/ C / Fortran
- solid knowledge in fluid mechanics
- solid knowledge in numerical methods for differential equations / CFD

Contact

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References

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