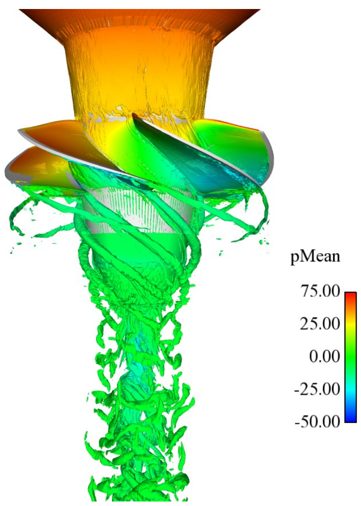
Streamline curvature effects in turbulence modeling of hydropower applications

A major field of research in computational fluid dynamics is concerned with the modeling of turbulence. Two-equation eddy-viscosity turbulence models are widely used in industrial CFD codes and have been found to be reasonably numerically robust and computationally efficient. Reynolds Stress Models (RSM) have the potential to significantly improve the flow predictions by incorporating more of the underlying physics, but they are not widely used in industry since they are difficult to use. Explicit Algebraic Reynolds Stress Models (EARSMs) are simplified Reynolds Stress Models that are much more numerically and computationally robust and have been found to be comparable to standard two-equation models in computational effort [1].

Turbulent flows over curved surfaces, near stagnation and separation points, in vortices and in rotating frames of reference are all affected by streamline curvature effects. In hydropower, the Reynolds number is high and there is a highly 3D unsteady periodic flow present, which is challenging for numerical modelling. The bladed geometry together with the complexity of the flow field lead the industrial engineers to stick to standard two-equation eddy-viscosity models. Those models however fail in describing effects of local as well as global rotation, and thus completely fail to predict the complex effects of turbulence. Strong curvature effects form a major cornerstone problem also at the Reynolds Stress Modelling level, and pressure-strain rate models that are able to accurately capture strongly rotating turbulence are rare. A curvature correction for explicit algebraic Reynolds stress models (EARSMs), in a streamline oriented curvilinear co-ordinate system is presented by Wallin and Johansson [2].

The objective of this thesis is to implement and validate the modelling of the streamline curvature effects in the available EBRSMs, and compare it with other available models which takes the streamline curvature into account. A successful implementation and validation of the model leads to a proposition of a new hybrid RANS-LES model. The model should be robust and easy to implement and use for hydropower applications.



Prerequisites
The student should have a good background in programming, CFD and turbulence modeling.

Supervisor: Ardalan Javadi, ajavadi@chalmers.se
Examiner: Håkan Nilsson, hani@chalmers.se

REFERENCES
[1] Wallin, S. & Johansson, A complete explicit algebraic Reynolds stress model for incompressible and compressible turbulent flows. J. Fluid Mech, 403, 89-132, (2000).
[2] Wallin, S. & Johansson, Modelling streamline curvature effects in explicit algebraic Reynolds stress turbulence models, Intl. J. Heat Fluid Flow, 23, 721–730, (2002) .