Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Flow Erosion

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Clusters
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Software
OpenFOAM

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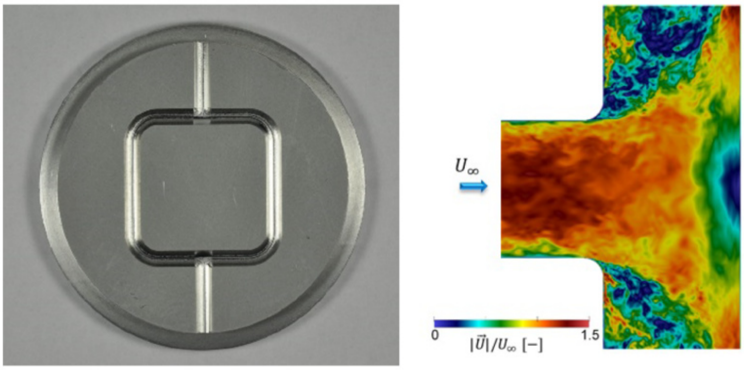

Figure 1: left: Water Spider Geometry. right: Instantaneous velocity field of the flow impingement in a T-Junction geometry.

Introduction

The underlying research project deals with the flow accelerated corrosion and erosion in cooling systems of combustion engines and their numerical prediction as well as the detection of critical flow configurations. The expected physical phenomena in such cooling systems are multifarious and include, beside the flow physics itself inter alia conjugated heat transfer, boiling effects, cavitation, erosion and flow accelarated corrosion. The challenging task of this project beside capturing the correct flow behavior is the merge of the listed phenomena and the prediction of the interaction between them within one numerical simulation especially with a reasonable computational effort.

Methods

The entire numerical work is based on the open source toolbox OpenFOAM® version 1912 of the ESI group for continuum-mechanical problems which is based on the Finite-Volume-Method (FVM) for numerical discretization of the governing equations, conservation of mass, momentum, energy and volume fraction. Depending on the observed problem, the velocity and pressure field are coupled by the Semi-implicit Method for Pressure Linked Equation (SIMPLE) for steady simulations and the Pressure-Implicit with Splitting of Operators (PISO) algorithm for unsteady simulations. The resulting system of linear equations is solved iterative using multi-grid methods. A speed up by parallelization is achieved by domain decomposition whereby mostly the Scotch library, designed to minimize communications costs between the sub-domains, is used. The described procedure can be considered state of the art in computational fluid dynamics.

Results

The results can be divided in three subsections, a feasibility study for a reference solution for the so called 'Water Spider Geometry', particle erosion and phase change due to heat input (boiling) and local pressure reduction (cavitation). The former is explained in more detail. Feasibility study for a reference solution The 'Water Spider Geometry' (figure 1 left) is the central sample geometry of the 'Flow Erosion' project and represents a complex flow configuration with several basic fluid mechanical geometries, e.g. flow impingement, deflection and unification with a pipe-like cross-section shape. The qualitiy of the results is difficult to evaluate with regard to the lack of numerical or experimental reference data in literature difficult to evaluate. For an evaluation of the solution quality, a reference solution of the 'Water Spider Geometry' will be pursued and as an initial step in the framework of a feasibility study, the possibilities and computational effort will be investigated. Therefore, the mentioned basic fluid mechanical geometries will be observed isolated in accordance with the scientific quality standard of a Large-Eddy simulation, here the common Smagorinsky model is used to estimate the necessary ressources for the entire 'Water Spider geometry'. An extensive grid study for the flow impingement, deflection and unification was done and the necessary grids were detected to ensure a modeled part of the turbulent kinetic energy of less than 20 %. Especially the correct prediciton of the flow seperation during the flow deflection in a 90° pipe bend is challenging and a high mesh density in this region is necessary. Representative for the feasibility study, the instantaneous velocity field of the flow impingement in a T-junction geometry is illustrated in figure 1 right.

Discussion

With regard reproducing the flow bevaior in cooling systems of combustion engines, the present results can be seen as the groundwork for the upcoming two years with the goal of developing a volume of fluid solver including phase change, particle tracking and surface degradation. Especially the phase change volume-of-fluid solver in combination with scale resolving turbulence models is a complex area with regard to numerical instability and still target of basic research.

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