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Large Eddy Simulation of turbulent flow on dimpled surfaces and Genetic Optimization of Heat Transfer Surfaces

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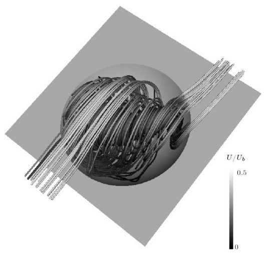
Vortex enhancement of heat transfer caused by turbulators is widely used in modern heat exchangers. In case of using dimples as turbulators the hydrodynamic and thermodynamic properties of exchangers become optimal in comparison with other heat transfer enhancement methods like ribs and fins. Especially with respect to the pressure loss this innovative cooling method shows major advantage as compared with existing conventional methods. To get a deep insight vortex formations in a narrow channel with a spherical dimple has been investigated using LES method in OpenFOAM. The flow separation is conducted by formation of fluctuating asymmetric vortex structures which enhance heat transfer on dimpled surfaces significantly by only a small increase of pressure loss.

Large Eddy Simulations (LES) are performed for single phase flow over a single spherical dimple and dimpled fields to analyse the occuring instantaneous vortex formations and their direct impact on the heat flux. Next to frequency analysis three dimensional proper orthogonal decomposition (POD) method (snapshot POD suggested by Sirovich[1] 1987) has been implemented in OpenFOAM and is carried out on LES pressure and velocity fields to identify a spatio-temporal structure hidden in the random fluctuations. Using POD technique tornado-like vortex structures are identified inside dimples which act as dominating modes with significantly large energy content in comparison to the other modes. Additionally, the galerkin projection of the Navier-Stokes equations onto the orthogonal subsystem determines energy transfer between coherent structures within the framework of POD. For inlet conditions a mathematic procedure[2] for generation of synthetic turbulent velocity fields with prescribed two point statistics, like spatial integral length scales, has been implemented and is used as boundary condition at the inlet patch for LES. Furthermore this method allows the user to predefine *rms*-values at the inlet to set time resolved correlated velocity fields which are strictly divergence free.

For further improvements a multi-objective design optimization algorithm to design the shape of a heat exchanger based on mesh motion algorithm is performend within in the framework OpenFOAM. Main importance is focused on speed up and robustsness during mesh motion and solution process. Based on mesh motion technique and the point displacement, which is randomly chosen from a gaussian pdf, the area of interest could assume any geometric configuration. There are no boundary conditions (like B-splines) which predefine the shape of the final heat exchanger surface. The aim of the procedure is to find the global maximimum, in this case the geometry most favorable to simultaneously maximize heat exchange while obtaining a minimum pressure loss.

In the presentation influence of inlet conditions, vortex formations, POD analysis and genetic algorithm in turbulent flows in a heat exchanger with dimples will be discussed.



Vortex structures obtained from LES velocity field

Streamlines of the spatial mode obtained from POD of the velocity field

Key words: LES, heat transfer, vortex, optimization

References

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