Experimental and numerical investigations of turbulent flows over complex surface with heat transfer and emission of passive scalars

Project leaders
S Kenjeres, CR Kleijn

Research theme
Complex dynamics of fluids
Mathematical and computational methods for fluid flow analysis

Participants
S Kenjeres, R Von Rohr,C Wagner, S Kuhn

Cooperations
R. Von Rohr, ETH Zurich

Funded
ETH Zurich, TU Delft, ERCOFTAC, HPC-Europa
1st 50% 2nd - 3rd 50%

Start of the project
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Information
S Kenjeres
015 278 3649
S.Kenjeres@tudelft.nl
www.msp.tudelft.nl

Project Aim

This is a joint project between Dept. of Multi Scale Physics at the TU Delft and the Laboratory for Transport Processes and Reactions of Prof. von Rohr at ETH Zurich. The project addresses the combined experimental and numerical study of turbulent flows over complex surfaces with heat transfer and distribution of passive scalars. The final goal is to perform in parallel state-of-the-art experiments (stereo PIV, LIF, TLC) and numerical simulations (LES, hybrid RANS/LES, DES, RANS) for different wall configurations over a range of Reynolds numbers and intensities of the wall heat flux and scalar emissions.

Progress

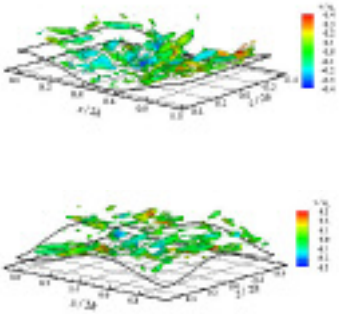
Measurements of turbulent forced and mixed convection flow and heat transfer over two-dimensional sinusoidal heated walls for 20<Re<30000 and 0<Ri<5000 have been performed at ETH Zurich. The first sets of numerical simulations have been performed at TU Delft - including a newly developed 4-equation elliptic relaxation RANS model and LES with dynamical Smagorinsky model. Comparison between experiments and results of RANS and LES (first and second-order statistics as well as local and integral distributions of Nusselt numbers and wall-friction coefficients) for Re=5600 demonstrated an excellent mutual agreement, as well as with spectral DNS results from literature. Dynamical LES have been performed for mixed convection situations at Re=20 - 2000, and the role of the coherent structures in wall heat transfer has been analyzed.

Dissertations

1. S. Kuhn (2008) , "Transport Mechanisms in Mixed Convective Flow over Complex Surfaces", Diss. ETH No.17627, co-supervision/co-promotion Prof. P. Rudolf von Rohr and Dr. S. Kenjeres, ETH Zurich, Switzerland.
2. C. Wagner (2008), "Transport Phenomena in Complex Turbulent Flows: Numerical and Experimental Methods", co-supervision/co-promotion Prof. P. Rudolf von Rohr and Dr. S. Kenjeres, ETH Zurich, Switzerland.

Scientific Publications

1. Kuhn, S., Kenjeres, S. and von Rohr, R. P. (2008), "Simulations of mixed convection over complex surfaces: a dynamical LES approach", Proceedings of the 7th International ERCOFTAC Symposium on Turbulence Modelling and Measurements, ETMM-7, 4-6 June 2008, Limassol, Cyprus, Vol.1, pp.262-267.
2. Wagner, C., Kenjeres, S. and von Rohr, R. P. (2008), "Comparative assessment of LES, DES and elliptic-relaxation based RANS for forced convection over wavy surfaces", Proceedings of the 7th International ERCOFTAC Symposium on Turbulence Modelling and Measurements, ETMM-7, 4-6 June 2008, Limassol, Cyprus, Vol.1, pp.256- 261.
3. Wagner C., Kenjeres S. and P. Rudolf von Rohr (2008), "Large-Eddy Simulations of Wall-Heat Transfer in Forced Convection over Two- and Three-Dimensional Wavy Surfaces", In the Proceedings of the 5th European Thermal-Sciences Conference, Eindhoven, 18-22 May, The Netherlends. Eds. Stoffels, G.G.M., van der Meer, T.H. and Steenhoven, A.A., ISBN-978-90-386-1274-4, Paper No. FCV-16, pp.1-8.
4. Kuhn S., Rudolf von Rohr P. and Kenjeres S. (2008), "Computational study of mixed convection over complex surfaces: comparative assessment of dynamical Large Eddy and Detached Eddy Simulations", In the Proceedings of the 5th European Thermal-Sciences Conference, Eindhoven, 18-22 May, The Netherlends. Eds. Stoffels, G.G.M., van der Meer, T.H. and Steenhoven, A.A., ISBN-978-90-386-1274-4, Paper No. MCV-6, pp.1-8.



Coherent structures in an instantaneous velocity field for a forced convection case over 2D (-left) and 3D (-right) wavy wall extracted by lambda_2 criteria colored by the vertical velocity component - results from a dynamic LES, Carsten, Kenjeres and von Rohr (2008).