Flow through Tetradecahedrons

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In modern compact heat exchangers complex internal structures are utilized to reduce pressure loss and/or to enhance heat transfer. Both features are directly linked to the flow through the exchanger, whereby a better understanding of the flow physics is a first step to introducing further improvements in performance. Heat transfer is characterized by the interaction of coolant flow with the surrounding structure. Forced heat convection increases where a high rate of fluid renewal/exchange at the heat exchanger’s surface occurs; hence the challenge becomes to choose the most appropriate heat exchanger surface geometry to maximize convective heat transfer. This challenge has recently taken on new dimensions, since modern manufacturing techniques, such as direct metal or ceramic laser sintering, allow internal structures of virtually any geometrical complexity to be realized.

To meet this challenge experimental investigations in which only integral quantities are measured (e.g. flow rate, overall heat flux, etc.) are not sufficient, since no information is available about the internal flow structure; hence no insight into the flow physics is gained. Numerical simulations (CFD) can be useful in this respect, but also simulations must be verified with experimental cases. Therefore, the need arises for experiments which provide detailed velocity field data in complex heat exchanger structures. For instance, Onstad et al. (2010) acquired the full three-dimensional, three-component velocity field inside a replica of an open-celled metal foam using magnet resonance velocimetry (MRV). These two steps, the experiments and the numerical simulations, are the focus of the present study, whereby the tetradecahedral (TDH) structure, as depicted in Fig. 1 and presented in Rezaey et al. (2013), has been examined as an internal structure, typical of porous media.

Fig. 1 Single TDH element as used for this study.

The three-dimensional and three-component velocity field inside a channel filled with tetradecahedrons was measured using Magnetic Resonance Velocimetry (MRV). The MRV data was verified by additional laser Doppler velocimetry (LDV) measurements. Numerical simulations at the same Reynolds number were performed for comparison.

Furthermore a completely novel approach has been introduced for estimating the heat transfer in this complex geometry, combining experimentally determined velocity data (MRV) with a numerically solved heat balance equation (FEM). While the results of this approach have not been validated in this study, the approach is novel and promises to greatly expand the usefulness and potential of data obtained using MRV, especially when evaluating problems involving passive scale contaminants, such as low heat fluxes or mixing of species.

References
