FLUID MIXING AT A T-JUNCTION

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Abstract

The paper gives an overview of T-junction mixing experiments carried out with wire-mesh sensors and related code validation activities. The mixing of coolant streams of different temperature in pipe junctions leads to temperature fluctuations that may cause thermal fatigue in the pipe wall. This is practical background for an increased interest in measuring and predicting the transient flow field and the turbulent mixing pattern downstream of a T-junction. The modeling task is quite challenging since transient CFD simulations are necessary. On the other hand, the flow in a T-junction is an excellent test case for steady-state calculations as well.

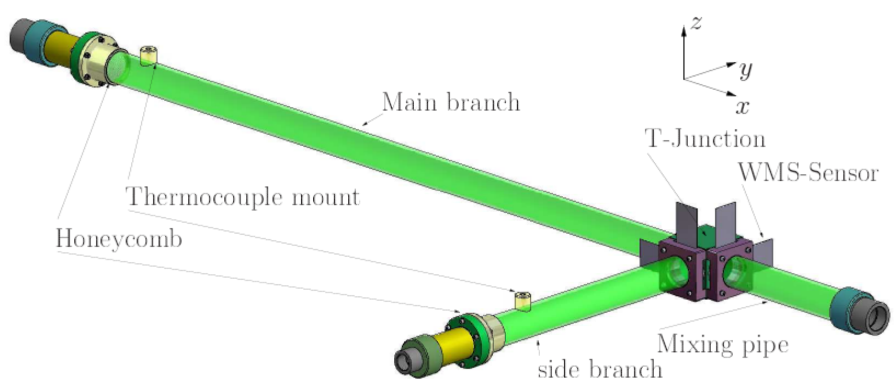

Fig. 1 T-junction for mixing studies

The presented experiments were carried out at a perpendicular connection of two pipes of 50 mm inner diameter (Fig. 1). The straight and the side branches were supplied by water of different electrical conductivity (tap water, desalinated water), the conductivity replaced the temperature as a model for the thermal mixing process. A set of three wire-mesh sensors with a grid of 16 x 16 measuring points each was used to record conductivity distributions downstream of the T-junction. In some experiments, one of the sensors was placed close to the inlet of the side branch in order to observe back entrainment of liquid in the main branch, which was found to occur at very low flow rates in the side branch. After a calibration to the conductivities of both inlet streams, the conductivity was transformed into a dimensionless mixing scalar with a time resolution of up to 10 kHz.

The data was used to check the accuracy of steady-state calculations with k-eps, SST (Shear Stress Transport) and RSM (Reynolds Stress Model). It was found that the RSM is best suitable to reproduce the time-averaged mixing scalar profiles downstream of the junction (Fig. 2). This includes the correct prediction of a recirculation region formed due to a flow separation caused by the side flow. The transport model for the mixing scalar is based on the assumption of an isotropic turbulent diffusion which is deduced from the local turbulent viscosity by defining a turbulent Schmidt number Sc_t. It was found that the use of the standard value of $Sc_t = 0.9$ results in a strong underestimation of the turbulent dispersion. Sc_t has to be decreased down to 0.1 in order to improve the agreement.

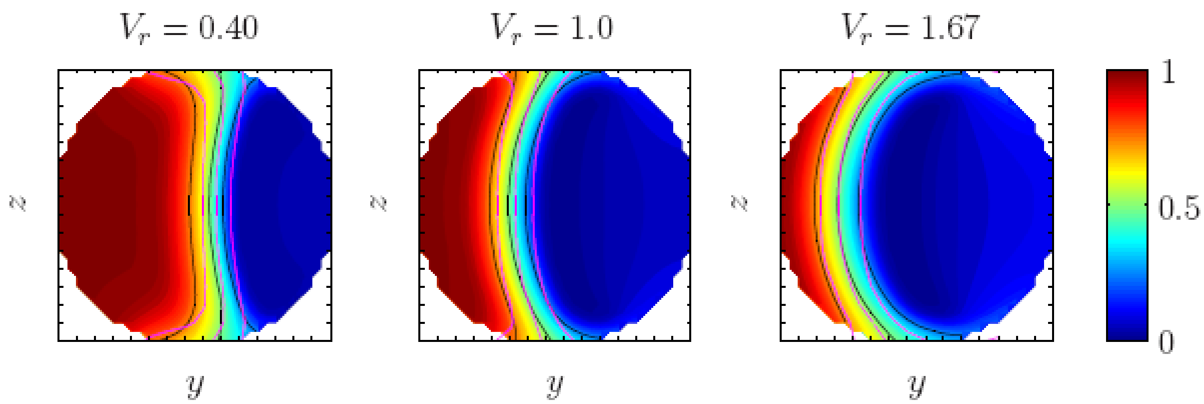

Fig. 2 Distribution of the mixing scalar x/D = 1 with different velocity ratio (side branch to main branch) calculated with the BSL Reynolds stress model and $Sc_t = 0.1$
Lines: contour-line of the mixing scalar = 0.25, 0.5 and 0.75, black: calculation, magenta: experiments

The advantage of wire-mesh sensors to provide two-dimensional distributions of the mixing scalar with a high time resolution was used to evaluate fluctuations of the mixing scalar. The statistical methods applied were: the calculation of distributions of the RMS value, a spectral analysis of the fluctuations and cross-correlation analyses. The latter were performed both between a pair of subsequent sensors to determine velocity profiles as well as within the measuring plane of the first sensor in the flow direction. Results will be presented in the paper. The mentioned analysis within a single measuring plane is carried out by cross-correlating the signal from a fixed measuring point of the sensor grid with all neighboring points. This method allows do visualize coherent structures like the recirculation region downstream of the side branch as well as to assess the scale of turbulent mixing structures.

Finally, a brief report on the status of LES calculations will be given. First results of a comparison of similar statistical quantities originating from the modeling and the mesh-sensor measurements will be shown. It is expected that this type of analysis will make a strong contribution to the validation of LES.