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Assessment of Turbulent Mixing in a Static Mixer Using Mean Age

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ABSTRACT

Static mixers are in-line motionless devices that are placed into a pipe to promote the blending of miscible fluids or dispersion of immiscible liquids. New designs of static mixers are continuously proposed to meet certain requirements of the final product. Instead of manufacturing numerous prototypes of inserts and conducting costly experiments to assess spatial and temporal mixing, it is suggested to use computational fluid dynamics (CFD) to visualize and quantify the efficiency of mixing in new insert designs. In this study, the mixing assessment of the Kenics mixer with six Kenics elements was performed by evaluating the mean age distribution for a range of Reynolds numbers between 1 and 12 000 covering laminar, and turbulent flow regimes. A single Kenics element can be described as a twisted ribbon like structure which can be fitted at the center of the pipe to act as an obstruction. The Kenics elements with clockwise and counterclockwise twist can be placed alternatively to form a Kenics mixer.

The age of a fluid molecule is equal to the amount of time elapsed since the particle has entered the system. The average amount of time required by a group of molecules (control volume, in case of continuum dynamics) to reach a certain location within the mixer is the mean age corresponding to that location.

Scalar plots of mean age were analyzed for each Reynolds number. Special emphasis was placed on the analysis of the turbulent flows. The frequency distribution of mean age was also evaluated at various cross-sections within the mixer for flow corresponding to different Reynolds numbers. The surface average distribution of mean age revealed multi-modal distributions of the mean age for turbulent flows. To quantitatively assess the mean age distribution in potential regions of adverse flow, a machine learning model called Gaussian Mixture Model was used to decompose the multimodal distribution into various gaussian curves which can be associated with specific regions or adverse flow across the Kenics mixer.