Novel Ultrafast Inline Mixing Process and Mixer Based on Receptivity

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Abstract

Many industrial processes require fast inline mixing technology to overcome the disadvantages from the mostly used stirred tanks. However, although current inline static mixers can enhance mass transfer in continuous operations and do not require a motor, drive shaft, or impellers, they have poor mixing efficiency, greater potential for fouling at low Reynolds number, and much higher pressure drop in turbulent flow. Traditional active flow control suffers from well-known saturation, and has limited capability to enhance mixing.

Fortunately a new inline fast mixing process based receptivity in confined free shear layers in a pipe has recently been discovered that can overcome the saturation barrier to achieve drastically rapid mixing. Here we demonstrate that fluid mixing (at least on the large scale) can be achieved even within one pipe diameter downstream of the inlet of the inline mixer under active periodical forcing. Statistical properties of concentration, such as average concentration, segregation intensity, probability distribution function (pdf) and power spectrum along transverse direction have been measured to qualitatively characterize the fast mixing process. The active initial excitation can force an initial laminar flow to transit into turbulence to enhance turbulent mixing. Ultrahigh spatial resolution measurement using laser induced fluorescence shows that conventional statistical properties of high Reynolds number (Re) flow can be realized at relatively low Re flow.

Since the optimized forcing frequency is nearly a constant, and independent on Re, and there is no possible other external excitation such as a motor blade, intuition tells us that resonance would be the reason that causes the fast mixing. Several parameters that could be related to the resonance frequency have been extensively investigated. These parameters include pipe length of the test section, length of the settling chamber, pipe diameter at the trailing edge, corner sharpness in the nozzle section, speaker for forcing, diameters of the membrane connecting the speaker and mixing chamber, with and without (connecting channel inlet directly to the faucet) the water tanks, two different water channels (i.e. Columbia's and Berlin's channel respectively) with some differences, such as material and structures, etc.. These extensive experimental studies have so far not been able to approve yet that resonance is the cause of the high receptivity and fast mixing. Instead, experimental evidence indicated that even if the resonance could have effect, it would be only a necessary condition, not the sufficient one.

In order to study the mechanism behind the high receptivity and rapid mixing process, velocity fields with and without forcing have been measured with Particle Image Velocimetry (PIV). Velocity fields with and without the forcing have been compared. Some changes in velocity field have been observed, and will be reported here as well.

In summary, the free shear layer in a pipe could provide a promising novel inline mixing process and mixer based on receptivity for process industrials.

keywords: Inline mixing, inline mixer, rapid mixing, turbulent mixing, mixing enhancement, receptivity, active flow control, confined free shear layer.

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