

How mixing performance in a batch OBC can be quantified is still an open question. Flow visualisation was used initially;^{19,20} then local and overall velocity profiles from particle image velocimetry;^{21,22} shear or strain rate;²³ ratio of axial to radial velocity components and axial dispersion coefficient^{24,25} evaluated from $\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2}$ in absence of flow. Apart from experimental studies, numerical simulations were also performed using dispersion rate,²⁶ stretch rate,²⁷ shear strain rate history,²⁸ axial and radial stretching capacity,²⁸ RTD,^{28,29} asymmetric double time,³⁰ mixing length and turbulent kinetic energy^{9,31,32} and mixing rate^{33,34} to provide the key indicators for assessing the mixing.

3.3.3 Mixing Evaluation in Two Phases

3.3.3.1 Liquid-Liquid

When two liquid phases are mixed in an OBC/COBC, one is often the continuous phase (the dominant one), another the discrete phase with generally different densities or/and viscosities from the main phase. A typical example of liquid-liquid mixing consists of an oil phase in an aqueous phase, which is the foundation of the suspension/emulsion polymerisation process. The oil phase (often monomer) must be dispersed as droplets in the aqueous phase as uniformly and small as possible so droplet size distribution is thus one of the key parameters for assessing the performance of mixing/reactor^{11,35,36} and for predicting final product properties, *e.g.* particle size distribution.³⁷ A variant from this is inverse phase polymerisation where an aqueous phase is dispersed as droplets in a denser phase (*e.g.* oil).^{38,39} Mixing delivers and maintains the balance of droplet breakage and coalescence, resulting in the onset droplet size distributions in either suspension or emulsion.⁴⁰ A wavelet method was used to analyse droplet and particle images⁴¹ and population balance modelling has been applied to evaluate breakage and coalescence rates in this type of system,⁴²⁻⁴⁵ while CFD predictions of oil droplet size distribution are still few and far between. Injecting a dye and analysing the colourimetry allowed the assessment of the mixing performance of two phases.⁴⁶ Manninen *et al.* (2013)⁴⁷ evaluated the axial dispersion coefficients when viscous non-Newtonian fluid as well as Newtonian fluids of different viscosities were involved in both moving fluid and moving baffle types of OBRs.

3.3.3.2 Solid-Liquid

There have been reports on solid-liquid mixing in OBR/COBR. Mackley *et al.* (1993) studied particle suspension in an OBR,⁴⁸ Liu *et al.* (1995) reported their study of carrot particle flow in a COBR^{22,49} and Gao *et al.* (1998) investigated particle flocculation in an OBR.⁵⁰ Crystallisation is an effective example of solid-liquid mixing during the formation of solid crystals and a