Characteristics of rotor-stator batch mixer performance elucidated by shaft torque and angle resolved PIV measurements

Authorship: H.H. Mortensen[1], L. Rosendahl[2] and R.V. Calabrese[3]

[1]Tetra Pak Scanima A/S, Denmark;
[2]Department of Energy Technology, Aalborg University,
[3]Department of Chemical & Biomolecular Engineering , University of Maryland

Abstract

Rotor-stator mixers are widely used in the process industries to carry out liquid-liquid homogenization, dispersion and emulsification as well as solid-liquid dispersion, dissolving and grinding. Unfortunately, only few archival publications concern these devices leaving the common user with little knowledge to theoretically predict or experimentally assess their performance. Design and scale-up of a given process is further complicated by the various geometrical parameters introduced by the presence of the stator, not least since most rotor-stator mixers can be fitted with various stator types differing by geometry, size and number of stator openings as well as by stator thickness, rotor-stator clearance and number of concentric stages.

In this study, characteristics of rotor-stator batch mixer performance have been elucidated by shaft torque and angle resolved 2D PIV measurements obtained in a full-scale, custom build, bottom-mounted, rotor-stator mixer unit operating in the turbulent regime with water as working fluid. Measurements have been acquired at various rotor speeds corresponding to impeller based Reynolds numbers between 2.0·E5 and 8.5·E5. The influence of various geometric parameters have been studied by systematic variation of the rotor-stator clearance gap, the stator opening size, the total stator opening area and the rotor-stator diameter. The use of transparent Plexiglass stators facilitated PIV measurements inside and outside the stator as well as into the stator slots themselves. The governing mechanisms controlling the complex flow structures, flow rates, power dissipation, absolute velocity fields, strain rate fields and turbulence intensity fields are explained, highlighting the influence on rotor-stator mixer performance. The results indicate that scale-up of rotor-stator mixer processes should be based on constant rotor-tip speed provided that geometry and size of stator openings, stator thickness, rotor-stator clearance gap and rotor blade width are maintained. Present data may serve as validation base for various turbulence models and/or CFD simulations of similar rotor-stator mixer devices and aid in development and/or validation of various mechanistic correlation models for prediction of e.g. drop- or particle size distribution.