Hydrodynamics of high gas-liquid ratio flows in a rotor-stator spinning disc reactor

HYDRODYNAMICS OF HIGH GAS-LIQUID RATIO FLOWS IN A ROTOR-STATOR SPINNING DISC REACTOR

Congress: ECCE10
Topic: Mixing / Multiphase flow

Presenting author: Michiel M. De Beer
Authors and affiliations : Michiel M. De Beer:Lab. Chemical Reactor Engineering,Eindhoven University of Technology,Eindhoven,Netherlands|Jos T.F. Keurentjes:Lab. Chemical Reactor Engineering,Eindhoven University of Technology,Eindhoven,Netherlands|Jaap C. Schouten:Lab. Chemical Reactor Engineering,Eindhoven University of Technology,Eindhoven,Netherlands|John Van der Schaaf:Lab. Chemical Reactor Engineering,Eindhoven University of Technology,Eindhoven,Netherlands

Abstract:
The rotor-stator Spinning Disc Reactor (rs-SDR) is a versatile continuous flow reactor aiming at intensification of (micro)mixing and intensification of mass and heat transfer rates for both single and multiphase processes [e.g. 1,2]. For such transfer processes the hydrodynamics of the fluids govern the performance of the reactor. While for a single liquid flow the hydrodynamics in the rs-SDR are relatively well understood [3], for gas-liquid flows only low gas-liquid volumetric flow ratios (φv,G/φv,L≤1) have been described [2]. However, in many applications (such as boiling/condensing fluids, gas absorption) much higher gas-liquid flow ratios are encountered. To be able to perform (and more important, to control) such processes using a rs-SDR, the current work presents gas-liquid hydrodynamics (using high-speed image analysis), and the accompanying pressure drop, for high gas-liquid flow ratios (φv,G/φv,L = 120).

The rs-SDR consists of a rotating disc (the rotor), enclosed by a stationary cylindrical housing (the stator). This results in a top and a bottom rotor-stator cavity. The gap between the rotor and the stator is small (1-2 mm). The high velocity gradient induces a strong shear force to act on the fluid in the rotor-stator gap.

In the top rotor-stator cavity the hydrodynamics at high gas-liquid flow ratios are found to be similar to the situation of low gas-liquid ratios: a thin liquid film flowing over the rotor surface. In the bottom rotor-stator cavity however, the observed gas-liquid regime heavily depends on gas-liquid flow ratio and rotational velocity. For low rotational velocities (ω < 40 rad s-1) and high gas-liquid flow ratios (φv,G/φv,L > 30) large, single gas bubbles periodically spill over the rim of the disc. In this situation little gas-liquid interaction occurs. With increasing rotational velocity two distinct regions are observed: a continuous liquid phase ring with dispersed gas bubbles at high radial positions and a continuous gas phase with a thin liquid film on the stator at low radial positions. The extent of the continuous gas phase region (covering up to more than half of the disc radius) is observed to increase with increasing gas-liquid flow ratio and to decrease with increasing rotational velocity. At sufficiently high rotational velocities the continuous gas phase region is no longer present; a full, stable gas dispersion is obtained. The holdup of small gas bubbles (db ≤ 0.1 mm) increases with increasing rotational velocity.

It is concluded that due to the centrifugal force of the rotor-stator Spinning Disc Reactor, well defined gas-liquid operating regimes are obtainable for very high gas-liquid ratio flows. Moreover, the highly dispersed gas bubble region increases the gas-liquid surface area (e.g. compared to annular flow) which further enhances the heat and mass transfer performance of the reactor.

Reference 1: M.M. De beer, l. Pezzi martins loane, j.T.F. Keurentjes, j.C. Schouten, j. Van der schaaf, single phase fluid-stator heat transfer in a rotor-stator spinning disc reactor, chem. Eng. Sc. 119 (2014) 88-89
Reference 2 : M. Meeuwse, J. van der Schaaf, J. C. Schouten, Mass transfer in a rotor-stator spinning disc reactor with co-feeding of gas and liquid, Ind. Eng. Chem. Res. 49 (2010) 1605-1610
Reference 3 : M.M. de Beer, J.T.F. Keurentjes, J.C. Schouten, J. Van der Schaaf, Engineering model for single phase flow in a multi-stage rotor-stator spinning disc reactor. Chem. Eng. J. 242 (2014) 53-61
Reference 4 :

Highlight 1: Gas-liquid hydrodynamics in a rotor-stator Spinning Disc Reactor presented.