Multiple rotor-stator spinning disc contactor: compact equipment for intensified multiphase processes

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The interphase mass transfer and heat transfer determine the equipment size of most multiphase processes, such as extractions, fast gas-liquid reactions, and heterogeneously catalysed reactions. Equipment with higher mass transfer rates than conventional equipment can be more compact. This leads to safer processes that demand less investment. The multiple rotor-stator spinning disc contactor, presented in this abstract, is a new type of compact apparatus for multiphase processes in which very high rates of interphase mass transfer are reached.

The spinning disc contactor

A stage of the multiple rotor-stator spinning disc contactor consists of a rotating disc in a cylindrical housing. The distance between the rotor and the wall (the stator) is small (order of magnitude typically 1 mm). A large velocity gradient, and thus a large shear force, is present due to the high rotational disc speed. The large shear force breaks up gas bubbles, in case of a gas-liquid system, or liquid drops, in case of a liquid-liquid system, resulting in a large two-phase interfacial area. The high energy input per unit volume induces a high degree of turbulence. This increases the surface renewal rate, which gives a high mass transfer coefficient. The combination of the large interfacial area and the high mass transfer coefficient leads to high volumetric mass transfer rates. The rotor-stator spinning disc contactor is therefore very suitable for gas-liquid or liquid-liquid processes, e.g. multiphase reactions, extractions, distillations, or absorption processes. The high degree of turbulence also leads to high liquid-solid mass transfer rates. In this latter case, the spinning disc contactor can be used as an efficient reactor for heterogeneously catalysed reactions with a catalytically active rotor and/or stator.

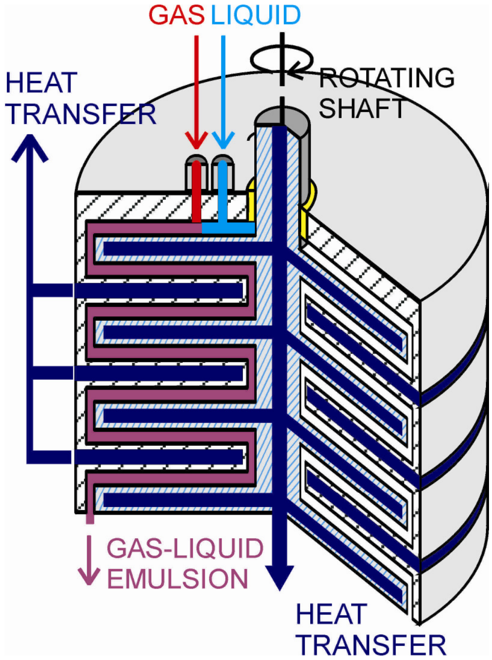

Figure 1. *Example of a multistage, co-current gas-liquid rotor-stator spinning disc reactor, with heat transfer fluid in the rotors and stators.*

Scaling-up of the spinning disc contactor is preferably done by scaling out. An industrial spinning disc unit would then consist of multiple sets of rotating discs, mounted on one axis, thus resulting in a series of rotor-stator unit cells (see Figure 1) with plug flow behaviour. Two phases can be contacted co-currently or counter-currently. The high rotational disc speed results in a high centrifugal force; a density difference between the two phases results in different, or even opposite, radial velocities, leading to counter-current flow. Gas bubbles, for example, will (virtually) always move towards the middle of the contactor, irrespective of the direction of the liquid flow. Heating or cooling can be performed via the rotors or stators, since the turbulence also has a positive effect on the heat transfer coefficient. This means that exothermic or endothermic reactions can be readily performed in a rotor-stator spinning disc reactor. A multi-spinning disc reactor can also be used for multi-step synthesis, if the rotors have different catalysts on their surfaces.

Gas-liquid contacting

Gas-liquid mass transfer is an important step in all gas-liquid operations that can be performed in the rotor-stator spinning disc contactor, e.g. absorption processes or heterogeneously catalysed reactions. The gas phase can be introduced in a single stage spinning disc unit in several ways: through a gas inlet in the bottom stator, or together with the liquid through the top inlet, as shown in Figure 2. In the former case, only the region between the rotor and the bottom stator is filled with gas bubbles; in the latter case, the reactor is divided into two regions: the liquid film on the top of the rotor with the gas phase on top, and the rest of the reactor, where small gas bubbles are dispersed in the liquid.

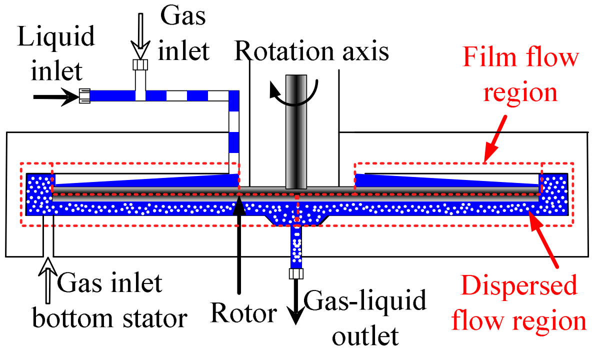

Figure 2. *Schematical drawing of a single stage of the spinning disc contactor. Rotor diameter 13.2 cm, rotor-stator distance 1 mm.*

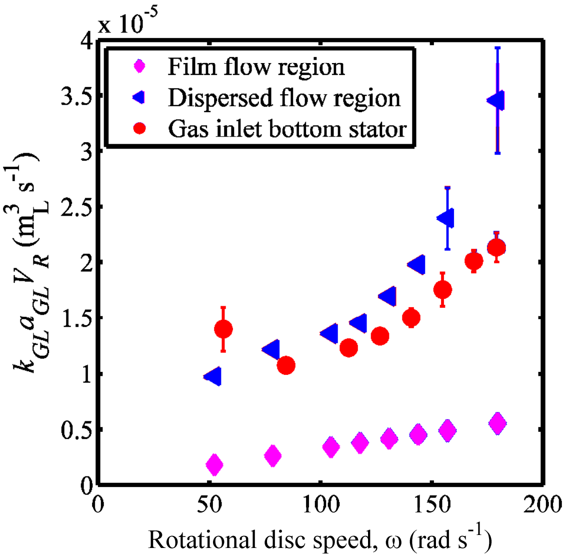

Figure 3. *Gas-liquid mass transfer rate.*[1]

The rate of gas-liquid mass transfer is shown in Figure 3, for the case of a single gas inlet in the bottom stator, where thus only the bottom part of the volume is used. The gas-liquid mass transfer increases with increasing rotational disc speed, up to 0.43 $m_L^3\ m_R^{-3}\ s^{-3}$, which is high in comparison to conventional reactors.[2]

By combining the gas and liquid inlets, the whole volume is now used for mass transfer. The film flow region and the dispersed flow region combined lead to a twofold increase in gas-liquid mass transfer (Figure 3).[1]

Liquid-solid mass transfer

The liquid-solid mass transfer coefficient also increases with increasing rotational disc speed, up to $3 \cdot 10^{-4}$ m s^{-1}, which is also higher than in conventional multiphase equipment. With the high liquid-solid interfacial area, due to the small gap between the rotor and the stator, this gives a volumetric liquid-solid mass transfer coefficient which is of equal order of magnitude as the overall gas-liquid mass transfer coefficient in the spinning disc contactor[2]. This makes the spinning disc contactor very suitable for heterogeneously catalysed reactions with a catalytically active disc.

The high interphase mass transfer coefficients and the broad range of possible configurations give the rotor-stator spinning disc contactor a high potential for multiphase processes. In particular cases a volume reduction of a factor of 10 to 100 seems feasible in comparison to traditional multiphase contacting equipment.

(1) M. Meeuwse et al.,*Ind. Eng. Chem. Res.,* **2009**, submitted.
(2) M. Meeuwse et al.,*Chem. Eng. Sci.,* **2010**, 65, 466-471.