Novel stator-rotor-stator spinning disc reactor for intensified integration of reaction and heat exchange

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The stator-rotor-stator spinning disc reactor (SDR) is a novel continuous flow reactor particularly aiming at intensified heat transfer rates for fast, highly exothermic reactions. For the "conventional" rotor-stator SDR (consisting of a rotating disc enclosed by a stationary cylinder, separated by an axial clearance in the range of a few millimetres) high rates of gas-liquid [1], liquid-liquid [2] and liquid-solid [3] mass transfer have been reported. These high mass transfer rates, caused by the high shear force acting on the fluid between the rotor and the stator, enable increased production rates of mass transfer limited processes. In case of highly exo- or endothermic reactions however, intensified heat transfer is necessary to accommodate these increased production rates. In the rotor-stator SDR heat is withdrawn from the reactor fluid through cooling channels inside the stator walls. Fluid-stator heat transfer coefficients increase with rotational velocity. However, effective overall heat transfer in the rotor-stator SDR is limited by stator wall conduction and cooling channel convection; a maximum overall heat transfer coefficient of U_{ov} = 1990 $Wm^{-2}K^{-1}$ is obtained for a single water phase, at a rotational velocity of ω = 40 rad s^{-1}.
The stator-rotor-stator spinning disc reactor addresses this issue. It consists of a stationary disc (the first stator), enclosed by a rotating cylinder (the rotor), which is again enclosed by a stationary cylinder (the second stator). In this way two rotor-stator cavities are created, separated by the common rotor. The axial clearance between the rotor and both stators is small, comparable to the rotor-stator SDR. In the stator-rotor-stator SDR, transfer of heat between two fluid streams is thus realised with a rotating heat transfer surface.
For a single water phase in both rotor-stator cavities the overall heat transfer coefficient increases with rotational velocity, from U_{ov} = 550 $Wm^{-2}K^{-1}$ at ω = 0 rad s^{-1} up to U_{ov} = 7000 $Wm^{-2}K^{-1}$ at ω = 100 rad s^{-1}. Similar to results obtained in the rotor-stator SDR, no influence of throughflow velocity on the heat transfer is observed; the heat transfer rates are determined by rotation. The fluid-rotor heat transfer coefficients obtained in the current work are in agreement with the values of fluid-stator heat transfer coefficients obtained in the rotor-stator SDR.
It can be concluded that in terms of heat transfer performance the stator-rotor-stator SDR is a major improvement compared to the rotor-stator SDR. Since the rotor-stator cavities are similar for both types of reactors, it is expected that mass transfer rates in multiphase reactions are equally high in the stator-rotor-stator SDR. This makes the stator-rotor-stator SDR a versatile multiphase reactor, where exo- and endothermic processes can potentially be integrated into a single reactor and where rotation simultaneously enhances both mass and heat transfer. A comparison is made with other compact heat exchanger/reactor concepts, such as microstructured and plate reactors, for the application of both single and multi-phase processes.

References

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