**Integrated Biofilm Reactor-Separator Using a Rotating Spiral Channel**

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**Highlights**

* Rotating spiral channel controls liquid-liquid contact between media and solvent
* Allows continuous control of nutrient and product concentration
* Preliminary result will be presented to demonstrate feasibility

**1. Introduction**

Industrial biotechnology aims to use microorganisms to transform one chemical species to another. Engineering systems to control the supply of nutrient species and the removal of product species must optimise production rate per cost. For continuous processing by biofilms - an aggregate of microorganisms attached to an abiotic surface1 - a surface must be provided with access to a flow of aqueous media to both sustain the biofilm and remove waste. The aqueous flow should be even over the biofilm, have a thickness that allows all of the media to be accessed and have a flow rate that is suited to the biofilm production rate. Indeed, the media supply may be used to optimise production conditions. It may also be helpful to bring a second, immiscible, liquid into contact with the aqueous phase to help control conditions in the medium, not least to separate the product species.

A rotating spiral channel allows such an arrangement of biofilm, aqueous media and an immiscible solvent liquid. The spiral channel rotating around its axis segregates the two fluid phases into parallel-flowing layers of adjustable flow rate and interface position. Fig. 1a shows a schematic of a typical cross-section of the channel. The biofilm is shown on the left hand side wall, stabilised there by the strong radial acceleration (*r*Ω2) and in contact with the denser aqueous media, which in turn is in contact with an organic solvent. The media and solvent are flowing in the direction perpendicular to the section, either co-currently or counter-currently.

(a)  (b) 

**Figure 1.** (a) Channel section with biofilm (on the left), aqueous media and solvent. Grey arrows indicate the secondary flow5 (from centrifugal and Coriolis accelerations) that assist species transfer. (b) Photograph taken from below of water and octanol flowing counter-currently in a rotating spiral channel.

**2. Background**

Rotating spiral channels allow contacting of two immiscible fluids at the optimum flow rate ratio of the two phases and ratio of the thicknesses of the two fluid layers2. Mass transfer coefficients that are orders of magnitude greater than those with conventional contacting methods have been demonstrated3. While that work considered gas-liquid contacting, ideal theory4 predicting interface position and flow rates in relation to fluid properties, rotation rate, pressure gradient and channel size applies equally to liquid-liquid and gas-liquid flows. Indeed, a number of informal tests with the same apparatus used for the gas-liquid work2,3 confirm it handles liquid-liquid contacting equally well. Fig. 1b shows an image from a test with water and octanol contacting counter-currently. The relatively high viscosity of the octanol means it occupies the majority of the channel cross section for the conditions of the test. This is predicted by the model which also shows that the interface could be moved to other positions by suitable choices for pressure gradient and rotation rate, while maintaining correct solvent flow rate, e.g. that to fully remove the product.

**3. Concentration control**

Product concentration will vary with position (*z*) along the channel both as it accumulates from biofilm production and as the product transfers to the solvent. Co-current flow of the solvent results in a steadily increasing product concentration (*C*) along the channel (Fig. 2a). By contrast, with counter-current flow of the solvent phase the concentration in the aqueous phase first increases rapidly as product is gained from the loaded solvent and then decreases as pure inlet solvent is encountered (Fig. 2b). Consequently, the biofilm media will have a more uniform bulk concentration. Increasing solvent flow rate is expected to reduce product concentration levels in the aqueous phase; decreasing channel size is expected to increase concentration uniformity. Thus, considerable control of product concentration in the biofilm environment should be possible.

 

**Figure 2.** Product concentration profiles along the channel for (a) co-current and (b) counter-current flow of solvent.

**4. Conclusions**

An existing and proven apparatus2.3 will be used to produce continuous biofilm processing in a rotating spiral channel with simultaneous product extraction into a counter-flowing solvent stream. A preliminary assessment will be presented at the congress.

**References**

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