An Investigation into the Micromixing Characteristics in a Spinning Disc Reactor

Salah Ramadan Al-hengari* **and Kamelia V.K. Boodhoo**

School of Chemical Engineering and Advanced Materials, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK

1. Summary

This paper concerns the characterisation of the micromixing process within a thin film flowing on the surface of a spinning disc reactor (SDR). A parallel-competitive reaction test scheme will be used to quantify micromixing in terms of the segregation index (Xs), micromixedness ratio (α) and micromixing time (t_m). The effects of various parameters will be investigated including disc rotation rates, feed flowrates, disc surface configurations (smooth, grooved, etc.), acid varying concentrations, liquid feed viscosities, and wetting characteristics of liquid feeds etc. The SDR mixing data will be benchmarked against experimental data for a conventional stirred tank reactor (STR) in order to evaluate the micromixing efficiency in the SDR relative to the STR.

Key words: *Process intensification; Micromixing characterisation; segregation index; Spinning disc reactor*

2. Extended abstract

2.1. Reaction System

The system considered in this work consists of three parallel-competitive reversible reaction used to quantify micromixing in terms of the segregation index. This scheme is known as the iodide / iodate system and it consists of the following reactions:

$$H_2BO_3^{-}{}_{(aq)} + H^{+}{}_{(aq)} \Leftrightarrow H_3BO_{3(aq)}$$ Quasi-instantaneous (1)

$$5I^{-}{}_{(aq)} + IO_{3(aq)} + 6H^{-}{}_{(aq)} \Leftrightarrow 3I_{2(aq)} + 3H_2o_{(aq)}$$ Very fast (2)

$$I_2 + I^{-} \Leftrightarrow I_3^{-}{}_{(aq)}$$ Equilibrium (3)

The second reaction (2) which is a redox reaction and is called Dushman reaction is fast, in the same range of the micromixing process, but much slower than the neutralisation reaction (1). The iodine formed reacts further with iodide ions I^- to yield I^-_3 according to the quasi-instantaneous equilibrium (Reaction 3). The degree of micromixing has a direct influence on Reaction 2 and subsequently on Reaction 3. The measurement of I^-_3 can therefore provide a good indication of the level of micromixing achieved in any given system. The lower the I^-_3 concentration, the lower is the segregation index, Xs, which means better micromixing. It is to be noted that

* Corresponding author (**E-mail: salah.al-hengari@ncl.ac.uk**)

for perfect micromixing Xs = 0, for total segregation Xs = 1 and for partial segregation Xs varies between 0 and 1.

2. 2.Experimental Rigs and Procedure

In this work, we will compare the micromixing data in terms of $\mathbf{X_s}$, $\mathbf{t_m}$ and α obtained in a semibach stirred tank reactor (STR) (Figure 1) and a spinning disc reactor (SDR) (Figure 2). In the STR, we will study the effect of impeller speeds (300-1200 rpm range), acid concentrations (0.5 - 4.0 M range), acid feed rate (1.0 and 2.0 ml/min) and positions of acid injection points in the reactor on the micromixing parameters $\mathbf{X_s}$, $\mathbf{t_m}$ and α. Two acid feeding point positions are being investigated: the first point is located at a distance of 5 mm from the edge of the impeller blade in the same horizontal plane whilst the second point is located directly above the first injection point, at a vertical distance of 35 mm. The two feed points are located at the vertical axis of symmetry of the reactor. These two feed points lie on a vertical line, at 0.1 T from the wall of the reactor, where T is the diameter of the reactor. The reactor is equipped with an acid feed tube of 1.78 mm internal diameter, which is connected to a syringe pump. In order to ensure a high level of accuracy in our measurements and to avoid disproportionation and iodine losses, the concentration of triiodine $[I^-_3]$ is taken online instead of offline, which has not been done previously. All the measurements were carried out using a double beam UV-Vis spectrophotometer (MCS500 Carl Zeiss Jena Gmbh) equipped with an online probe dipped into the solution. All experiments are to be carried out at 20°C.

The spinning disk reactor (SDR) creates highly sheared thin liquid films (Figure 2) which have been shown to have excellent heat/mass transfer properties. Liquid is supplied to the disc at or near its centre and is flung outwards towards the disc periphery by the centrifugal acceleration. Depending upon the liquid viscosity, the disc speed, the feed flowrate and the size of the disc, the film can be as thin as 50 μm and very high shear rates can also be generated within the film. Such high shear rates are expected to result in good micromixing which we intend to investigate experimentally.

Experiments are currently underway to characterise the micromixing in the semi-batch reactor and the spinning disc reactor as described above. We hope to demonstrate quantitatively that the micromixing achieved in the thin highly sheared films in the SDR is significantly better than that obtained in a stirred tank vessel operating under optimised conditions.

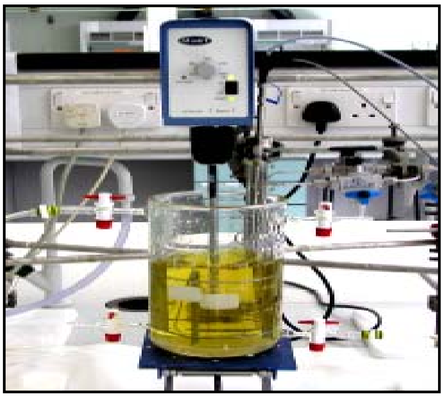

Figure (1): - Semibach stirred tank reactor rig

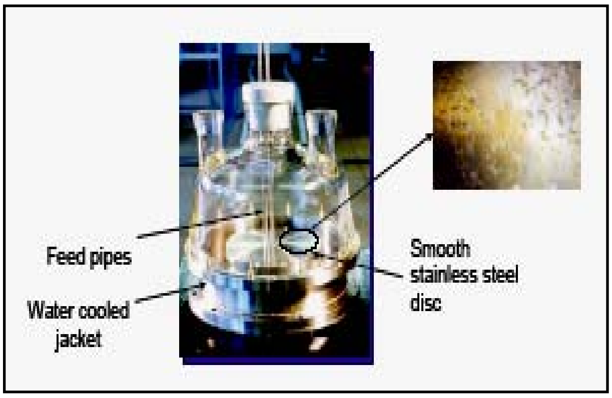

Figure (2): View of a SDR and thin film flow