

Complex dynamics in mass-coupled flow-through chemical reactors with a pH-oscillatory reaction

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Reaction between hydrogen peroxide and thiosulfate catalyzed by Cu^{2+} ions (HPTCu) in an isothermal stirred flow-through reactor is an autocatalytic chemical oscillator with large amplitude pH variations. In these pH regulated reactions the concentration of hydrogen ions plays a critical role in the dynamical behaviour of system. The oxidation reduction reaction between H_2O_2 and $\text{S}_2\text{O}_3^{2-}$ in the presence of catalytic amount of Cu^{2+} has been shown to exhibit a rich variety of dynamical behavior if it is carried out in a continuous flow stirred tank reactor (CSTR). Dynamics of the system in one CSTR was initially examined by Orban and Epstein (1987). They found that pH of the system corresponds to: steady state I (SSI) with $\text{pH} = 7-9$, steady state II (SSII) with $\text{pH} = 5$, steady state III (SSIII) with $\text{pH} = 3.5$ and oscillations. In addition, the steady states may coexist and the system will operate at one of the alternative attractors depending on its history. In our earlier work we found that there are also parameter regions, where the system is excitable to pulsed addition of selected chemical species. In this work we report on experiments in a cascade of two reaction cells coupled via an opening for mass transfer. In particular, we studied synchronization between two oscillators. The change of dynamical behavior is monitored by a pH electrode in each reactor as the flow rate k_0 is stepwise varied. The recorded time series are used to construct one parameter diagrams where the dependence of pH in both reactors on the flow rate (reciprocal residence time) in the first reactor is represented. The system can be found in a combination of the four aforementioned dynamical regimes, the state of system depends on direction of changes of flow rate thus its history and the reactors influence each other. Series of experiments for various coupling strength are summarized in bifurcation diagrams, which are plotted in the parameter plane of the flow rate and mass transfer coefficient. These diagrams show that the coupling causes disappearance of bistability between SS II and SS I in the first reactor and an extinction of oscillations in the second reactor, where oscillations are replaced by SS III. The studied system serves as a representative model for more complex biochemical and biological systems that are frequently pH-sensitive and can be represented as coupled subsystems.