Analysis and control of tubular reactors

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Abstract – This research activity deals with the analysis and control of tubular reactors that cover a large class of distributed parameter in the field of (bio)chemical systems. Results cover a wide spectrum from observability/controllability analysis to the implementation of controllers on industrial processes via the stability analysis of the multiple steady states.

Tubular reactors cover a large class of (bio)chemical systems as encountered in industry and real-life applications. They are basically characterized by the non-homogeneity of the reacting medium within a confined volume (the reactor), and their dynamics are described by partial differential equations. With that respect, they belong to the class of dynamical systems known as infinite dimensional systems.

There are basically two classes of tubular reactors, one for which the hydrodynamics are purely convective (they are known as "plug-flow" reactors), the other described convective-diffusive hydrodynamics. Plug flow reactors are known in chemical reactor design as the best basic reactor configuration in the sense that it allows to maximize the conversion. Convective-diffusive reactors represent an intermediate class of reactors between the plug flow reactor (when the diffusion coefficient(s) is(are) to zero) and the continuous stirred tank reactor (CSTR) (when the diffusion coefficient(s) tend(s) to infinity).

Figure 1: Picture of a tubular reactor (fixed-bed reactor for anaerobic digestion).

The research activities are oriented in multiple directions.

- Modelling and identification of tubular reactors, including anaerobic digestion fixed bed reactor and denitrifying biofilter (e.g. [1])
- Analysis of the observability and controllabality of tubular reactors, and the related issue of sensor and actuator location (e.g. [1][2][7][8])
- Analysis of the existence and stability of multiple equilibrium profiles in tubular reactors (e.g. [4])
- Numerical and mathematical analysis of the reduction methods applied to tubular reactor partial differential equations in order to obtain a set of ordinary differential equations (e.g. [3][6])
- On-line state and parameter estimation of tubular reactors, including the application of ETBE synthesis process and denitrifying biofilter (e.g. [3])
- Control design for tubular reactors, including adaptive extremum seeking approches (e.g. [1][3][5])
- Control applications, including anaerobic fixed bed reactors and denitrifying biolfilter (e.g. [1])

As a matter of example, one key issue is to emphasize the conditions under which multiple equilibrium profiles may appear non-isothermal tubular reactors. On one hand, it is well-known in chemical process dynamics that the CSTR may exhibits three equilibrium points. On the other hand, the plug flow reactor can exhibit only one equilibrium profile due to the form of its boundary condition (only one boundary condition at the reactor inlet characterized by a scalar relation). One will therefore expect that the convective-diffusive configuration will be able to exhibit multiple equilibrium points if it is far enough from the plug flow reactor and close enough to the CSTR. This situation has been carefully studied and the results provided in [4] shows that multiple equilibrium profiles may exist if the diffusion coefficient(s) is(are) large enough.

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