Control of a Tubular Reactor using POD and MPC

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1 Introduction

The dynamics of tubular reactors are typically described by nonlinear PDEs (Partial Differential Equations) which are derived from mass and energy balance principles. The control of such systems can be addressed by transforming the PDEs and the boundary conditions into a set of ODEs (Ordinary Differential Equations), which would make possible the application of the control theory developed for lumped parameter systems. However, the design of the controllers would be very difficult or practically impossible due to the high order models obtained of discretizing the PDEs. Therefore, it is necessary to find reduced-order models that make possible the design of the control schemes. This can be done by means of a Proper Orthogonal Decomposition (POD) and Galerkin projection. This is the approach followed in this work.

2 Control of the Reactor

Proper Orthogonal Decomposition is a technique that has been applied in many physical systems governed by PDEs for deriving reduced order models. The advantage of applying this technique is the incorporation of simulation or experimental data as well as the existing physical relationships (when the Galerkin projection is used) from the original model [1]. This work presents the application of POD and Predictive control techniques to the control of the temperature and concentration profiles of a non-isothermal tubular reactor. The control goal is to keep the operation of the reactor around a desired operating concentration and temperature profiles in spite of the disturbances that affect the reactor, that is the changes in the temperature and concentration of the feeding flow. The manipulated variables of the control system are the temperature of the jacket sections that wrap the turbular reactor. The model on which the MPC is based was derived as it is explained in the following lines. Around the operating profiles (concentration and temperature) the nonlinear PDEs that model the reactor are linearized, and afterwards the resulting linear PDEs are discretized in space giving as result a high order linear model (600 states). Then a reduced order model of only 20 states is found by means of the POD technique. Finally a discrete-time version of the linear POD model is derived.

3 Results and Future research

Typically the variations in the temperature and concentration of the feeding flow of a tubular reactor are $\pm 10^{\circ}$K for the temperature and $\pm 5\%$ of the nominal value for the concentration. Keeping in mind these magnitudes, two disturbance rejections tests were carried out. In spite of the spatial discretization of the nonlinear PDEs that model the reactor, the linearization and discretization in time of the equations, and the dramatic reduction of model order by means of POD (from 600 states to 20 states), on which the controller is based, the controller performed well. However, if larger disturbances are applied to the tubular chemical reactor, the behavior of the MPC controller would not be as good as it was during the tests, since the differences between the nonlinear model and the linear model and consequently the linear POD model would be more significant. Therefore in future work, the nonlinear characteristics of the process should be taken into account in order to design controllers with a higher degree of robustness.

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References

[1] M. Hazenberg, P. Astrid and S. Weiland, "Low order modeling and optimal control design of a heated plate", *in Proceedings of the 5th European Control Conference*, Cambridge, 2003.