398a Start-up and Feedback Control of Autothermal Reforming Reactors

Donald J. Chmielewski, Yongyou Hu, and Dionissios D. Papadias

Fuel cells for transportation propulsion and auxiliary power applications have shown great promise with respect to efficiency and environmental benefit. Unfortunately, in these mobile type applications the delivery of fuel is a substantial hurdle to commercial viability. Although the availability of pure hydrogen would yield a simple power generating system with high efficiency and fast response time, the large cost associated with hydrogen storage and distribution makes this option mush less attractive. Alternatively, high energy density fossil fuels have the advantage of an existing, low cost storage and delivery infrastructure.

Assuming a hydrocarbon fuel, the typical hydrogen plant consists of a reforming unit followed by a number of reactors charged with reducing the sulfur and CO content of the product stream (both of which are poisons to the low temperature PEM fuel cells targeted for automotive applications). While the design and configuration of these clean-up reactors is still in flux (due to competing technologies and the possible development of a sulfur/CO tolerant fuel cell) it is perceived that the reforming reactor will be a key component of nearly all future hydrogen plants. As such, in this effort we will focus on the reforming process.

During start-up of an Autothermal Reforming (ATR) reactor, there are two modes of operation. The first is the Catalytic Partial Oxidation (CPOX) mode, where only fuel and air are fed to the reactor. The goal of this mode is to quickly raise the temperature of the catalyst support. Then the reactor will move into the ATR mode through the addition of steam. Unfortunately, this steam will significantly reduce reactor temperature and may even extinguish the reactor. In response to this temperature dip, one should simultaneously increase the air flow rate. However, this flow should be increased in such a way that the reactor temperature does not exceed operational limits and possibly damage catalyst activity.

In this work we present transfer function models for an ATR reactor and propose a feedback control scheme aimed at temperature regulation. The proposed control structure employs air feed rate as the manipulated variable, and in regulation mode must face disturbances in the feed temperature as well as fluctuations in the measured reactor temperature. Another important disturbance (as defined by the proposed control structure) is the fed of steam to the reactor. Toward fast temperature rise, this feed is withheld in the initial phase (CPOX mode), and then gradually increased so as to achieve higher steam reforming and water gas shift reaction rates (the ATR mode). Mitigating the temperature dip associated with the transition from CPOX mode to ATR mode, is a primary challenge facing ATR operation. Thus, our investigation includes an analysis of the feed-forward control structure as a means to minimize the mode transition time.