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MODEL-BASED CONTROL SYSTEM DESIGN IN A UREA-SCR AFTERTREATMENT SYSTEM BASED ON NH_3 SENSOR FEEDBACK

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ABSTRACT−This paper presents preliminary control system simulation results in a urea-selective catalytic reduction (SCR) aftertreatment system based on NH_3 sensor feedback. A four-state control-oriented lumped parameter model is used to analyze the controllability and observability properties of the urea-SCR plant. A model-based estimator is designed via simulation and a control system is developed with design based on a sliding mode control framework. The control system based on NH_3 sensor feedback is analyzed via simulation by comparing it to a control system developed based on NO_x sensor feedback. Simulation results show that the NH_3 sensor-based strategy performs very similarly in comparison to a NO_x sensor-based strategy. The control system performance metrics for NO_x index, urea index, urea usage, and NH_3 slip suggest that the NO_x sensor can be a potential alternative to a NO_x sensor for urea-SCR control applications.

KEY WORDS : Urea-SCR catalyst, Model-based estimation, Observer, Control system design, NH_3 sensor, Sliding mode control

1. INTRODUCTION

Urea-SCR catalysts are regarded as the leading NO_x aftertreatment technology for compliance with the 2010 NO_x emission standards set by the US EPA (Environmental Protection Agency) for heavy duty diesel engines. SCR catalysts have long been used for NO_x reduction in stationary applications such as power plants and industrial reactors (Tronconi *et al*., 1996). In such applications, NH_3 is introduced directly into the catalyst, which reduces the NO_x in the flue gases. With regards to mobile sources, urea-SCR catalysts are a proven technology in Europe for meeting Euro III and Euro IV diesel engine NO_x standards (Schar *et al*., 2006). A urea solution spray is injected into the exhaust gas upstream of the SCR catalyst. At sufficiently high exhaust gas temperature, the urea droplets evaporate and mix with the exhaust gas. NH_3 is formed as a result of urea decomposition and HNCO hydrolysis reactions in the exhaust pipe and in the SCR catalyst. NO_x is reduced to N_2 via several SCR reactions aided by the catalyst.

The urea-SCR catalyst must be actively controlled to ensure high NO_x reduction, low NH_3 slip, and low urea consumption. NO_x sensors are placed downstream of the SCR catalyst to provide NO_x feedback to the closed loop control system in order to determine the urea injection rate necessary to minimize NH_3 slip and maximize NO_x conversion efficiency. The state-of-the-art NO_x sensors have cross-sensitivity to NH_3, which is a limitation for accurate NO_x feedback. This limitation can be overcome to certain extent through a NO_x sensor model with the objective of determining the components of the NO_x sensor signal. To implement this strategy on a vehicle, for example, using an FTP (Federal Transient Procedure) cycle, an accurate NO_x sensor model is needed to reduce NO_x and NH_3, a topic which is not addressed in the literature.

Another approach used to overcome this limitation is to use an NH_3 sensor, developed by Delphi (Wang *et al*., 2007) and in the process of testing for SCR control applications. NH_3 sensors, which are relatively new to automotive applications, have been researched from a materials standpoint in Europe in order to meet the NO_x emission regulations (Moos *et al*., 2002). Additionally, Wingbrant *et al.* developed a MISiC-FET (Metal Insulated Silicon Carbide Field Effect Transistor) for detection of NH_3 in SCR systems (Wingbrandt *et al*., 2005). The authors concluded that the presence of water vapor was shown to have the largest effect on the sensors at low levels. Because the NO_x sensors are limited for closed loop SCR control applications because of the sensor's cross-sensitivity towards NH_3, NH_3 sensors are being explored as an alternative (Wang, 2007). This gives the motivation for the study and analysis of the NH_3 sensor in simulation for possible SCR control applications. This paper focuses on the development of a model-based estimator and control strategy based on NH_3 sensor feedback and compares its control system performance in simulation to a control strategy based on NO_x sensor feedback.

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