ABSTRACT

Selective Catalytic Reduction (SCR) is a well-known method of reducing Nitrogen Oxide (NO_x) emissions from stationary and mobile diesel engines. Due to the growing need for retrofit SCR systems in diesel engines, significant progress must be made in improving catalyst activity, injection controller, and by-product minimization. This thesis presents the design and development of retrofit SCR and fast-SCR systems for a stationary constant-speed diesel engine. The performance of retrofit system is improved with SCR catalyst and then combined with pre-oxidation catalyst, with and without a mixer. Control of SCR systems for a constant-speed stationary diesel engine as well as automotive diesel engine, represented by linearized third order and fourth order state-space models using Discrete-time Super-Twisting Sliding Mode Controller (DSTSMC) are carried out.

The first work is about the design and fabrication of an expansion chamber, catalytic substrate, mixer, and urea injection elements of SCR and fast-SCR systems for a stationary diesel engine. A pair of ceramic monolith substrates are selected and, coated with cerium oxide and copper-zeolite for pre-oxidation and SCR catalyst, respectively. The catalyst for SCR and fast-SCR systems that have been synthesized are analyzed by various physio-chemical characterization methods.

In the second work, the experimental investigation of NO_x conversion efficiency of SCR system for the stationary diesel engine under Non-Road Steady Cycle (NRSC) is performed. The emission reduction by the retrofit system and the engine performance indicators are evaluated with the SCR catalyst and then combined with pre-oxidation catalyst, with and without a mixer. From the results, it is observed that the fast-SCR retrofit system with a mixer has a better NO_x conversion efficiency and, a lower engine Brake Thermal Efficiency (BTE) than the other combination of retrofit systems at a maximum Brake Power (BP) condition.

The third work is about the control of SCR system for a constant-speed stationary diesel engine, represented by linearized third order and fourth order state-space models using DSTSMC. The third order model of SCR system considers the effect of SCR catalyst only, while the fourth order model of SCR system incorporates the combined effect of Diesel Oxidation Catalyst (DOC) and SCR catalyst. The exhaust pollution levels of a stationary diesel engine during NRSC, are applied as input disturbances to the SCR system. Simulation work of closed loop responses obtained with the DSTSMC applied for the control of SCR system, represented by linearized third order and fourth order state-space models, have higher de-NOx efficacy than the open loop experimental results. The fourth order state-space model of SCR system considers NO and NO_2 exhaust concentrations, resulting in the maximum de-NO_x efficiency and negligible NH_3 slip.

The last work is about the control of SCR system for automotive diesel engine, represented by linearized third order and fourth order state-space models using DSTSMC. The third order model of SCR system consists of lumped single-cell SCR catalyst, while the fourth order model of SCR system includes a combined effect of DOC, Diesel Particulate Filter (DPF), and lumped single-cell SCR catalyst. The exhaust pollution levels of United States (US)06 driving cycle obtained from a medium duty diesel engine are applied as input disturbances to the SCR system. Simulation work of closed loop responses obtained with the DSTSMC, applied for the control of SCR system in automotive diesel engine, represented by fourth order state-space model considers the NO and NO_2 exhaust concentrations, resulting in higher de-NO_x efficiency and lower NH_3 slip than the third order state-space model.