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An Experimental Study on Urea Injection Uniformity in SCR Systems Using a Uniformity Index-Based Multi-Channel Analysis System

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This study aims to develop a Uniformity Index (UI)-based evaluation system for quantitatively analyzing urea injection uniformity in Selective Catalytic Reduction (SCR) systems. In diesel engine SCR systems, the suppression of NOx emissions through urea injection critically depends on the uniform mixing between the reductant and exhaust gas. Although various mixer designs have been developed to improve mixing performance, most previous studies have been limited to qualitative analyses or localized measurements, resulting in limitations in quantitatively evaluating injection uniformity within the flow field. In this study, a multi-channel analysis system consisting of 19 porous tubes was designed, with a unit injector (UI) installed at the end of each channel. The injected urea solution passes through a mixer and is distributed into each channel, where solenoid valves (S/Vs) are installed. These valves are connected to a National Instruments (NI) board and sequentially controlled using a MATLAB-based control algorithm, enabling time-resolved and channel-specific sampling. In addition, a Pulse Width Modulation (PWM)-based control system was implemented to regulate the current and voltage supplied to the injector, allowing precise control of injection quantity and spray characteristics. Gas concentrations were measured using Fourier Transform Infrared (FTIR) spectroscopy, focusing on NH_3 as the key species representing urea decomposition and distribution characteristics. The measured data were used to calculate the Uniformity Index (UI), where a lower UI value indicates a more uniform distribution. Furthermore, a MATLAB-based post-processing and visualization algorithm was developed to represent the NH_3 concentration distribution across the 19 channels in a color-coded cross-sectional format, enabling intuitive visualization of spatial concentration variations. The results demonstrate that the proposed system effectively quantifies urea injection uniformity and provides clear insights into NH_3 distribution and mixing characteristics through both numerical evaluation and visual representation. This study suggests that the proposed approach can serve as a practical experimental and analytical platform for improving mixing uniformity and optimizing NOx reduction performance in SCR systems.

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