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Study on Model-Based Development for Lean NOx Trap (2nd Report)

- Modeling Oxygen Storage and NOx trap property of LNT -

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Numerous studies have been carried out on the modeling of Lean NOx Trap (LNT) in diesel engine exhaust aftertreatment systems. In these previous studies, for the purpose of highly accurate simulation of the properties of oxygen storage materials (OSM) and NOx storage materials that constitute LNT, catalyst models composed of detail kinetics and/or complex global kinetics have been proposed. Continuing from our previous report(1), we tried to develop a simple and highly accurate LNT model as a tool for Model-based development (MBD) with the goal of achieving both simulation accuracy and reducing the man-hours and work period.

For the OSM, a highly accurate single-site model was developed by introducing oxygen coverage dependence to the activation energy of OSM reduction. For the NOx trap material, a multi-site model consisting of three NOx trap sites and five reaction pathways was developed. In addition, NOx saturation dependence to the activation energy in the desorption process of NOx from the three NOx storage sites was introduced for improving the accuracy of the simulation. As shown in Fig. 1, the simulation results of LNT model show the good correlation to the experimental results in NOx absorption under lean condition, NOx desorption when switching from lean to rich, and emission NH_3 and N_2O under rich condition. Furthermore, simulation results show the good accuracy in the timing of H_2 generation under rich condition. This result indicates that mass balance of the complex redox process during LNT regeneration can be accurately simulated. Since H_2 generation under rich condition is known to be an important signal for controlling lambda value during LNT regeneration(2), it is also shown that the LNT model can be used for MBD of lambda control.

Next, we created a procedure for identifying the rate constants included in the reaction model, and calculated the man-hours and period required to it. We proposed a procedure for identify parameters of LNT model consisting of 23 tests by using synthetic gas bench and 26 steps optimization of reaction rate constants by optimizer. The man-hours and period required to develop one LNT model with this procedure were 190 hours and 8 weeks, respectively (Table 1).

Finally, we summarized the improvement effect and future work on using the developed LNT model for MBD. Since the developed LNT model can perform highly accurate simulations, it promotes model-based system design and control, and contributes to the reduction of man-hours in development process. However, the developed LNT model itself still requires a lot of work time, which may offset the reduction in man-hours in the development process. In the future, as an optimal tool for MBD, it will be important to improve not only simulation accuracy but also shortening the man-hours and period for modeling.

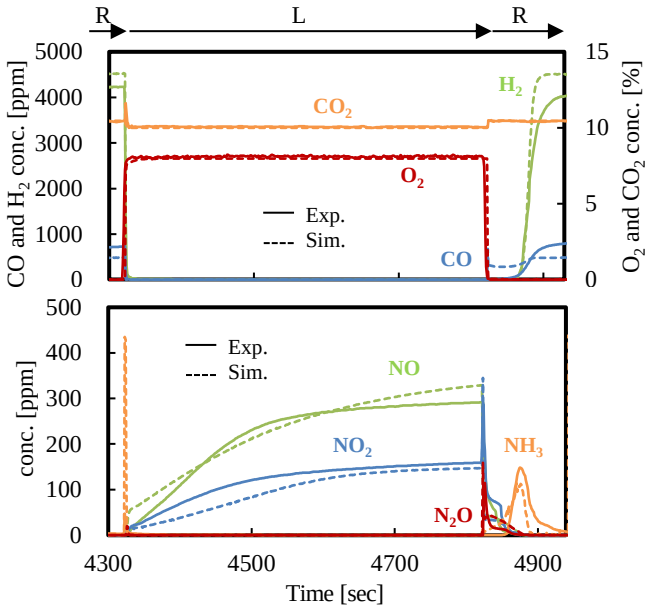

Fig. 1 Simulation results of NOx trap_CO test (300℃)

(1) Ohori, T. et al.: Study on Model-Based Development for Lean NO_x Trap, Transactions of Society of Automotive Engineers of Japan, Vol.53, No.1, p.32-37, (2022)

(2) Breitegger, B. et al.: Regeneration control of a LNT via a dynamic NOx-Sensor, 14. Internationales Stuttgarter Symposium, p.581–595, (2014)

Table 1 Man-hours and working period for LNT modeling

Working procedure	Man-hours (h)	Working period (week)
Synthetic Gas Bench testing	70	2
Parameter optimization	100	6
Reporting	20	
total	190	8