

Improvement of HC and NOx Conversion Rate by Detecting the Oxygen Storage Amount in the Catalyst at Restart of 100% Electric Drive HEV

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Carbon neutral mobility requires powertrains that reduce CO₂ emissions while maintaining clean emission performance. In a 100% electric drive hybrid electric vehicle (HEV), engine operating time is reduced by motor driving. However, the engine must still operate with high efficiency and low emissions when power generation is required. Therefore, exhaust emission reduction during engine restart after catalyst warm-up is an important issue for HEV.

During motor driving, there is no exhaust heat supply to the catalyst from engine, and the catalyst temperature decreases due to vehicle cooling air. The temperature decreases more in the under-floor catalyst than in the close-coupled three-way catalyst (C.C. catalyst). Therefore, at engine restart after long motor driving, purification by the C.C. catalyst becomes especially important.

The exhaust emission behavior at restart is strongly affected not only by catalyst temperature but also by the Oxygen Storage Amount (OSA) in the C.C. catalyst. If OSA remains excessively in the front-stage catalyst, reducing agents like HC, CO are consumed by stored oxygen and NO_x reduction is delayed. In contrast, if OSA becomes lower in the rear-stage catalyst, HC oxidation performance decreases. Thus, appropriate OSA behavior along the catalyst flow direction is required to improve the HC-NO_x trade-off.

In this study, OSA behavior during engine restart was investigated by both catalyst reaction analysis and multi-point O₂ sensor measurement. O₂ sensors were installed along the flow direction of the C.C. catalyst, and rich detection timing at each sensor position was used to understand OSA consumption behavior. The measured responses showed that OSA was consumed sequentially from the upstream side, which was consistent with the analysis result.

The analysis and experiment indicated that rapid OSA consumption in the front-stage catalyst is effective for NO_x reduction, whereas OSA retention in the rear-stage catalyst is effective for HC reduction. Based on this finding, an OSA control concept was developed in which an intermediate O₂ sensor detects the rich arrival at the front-stage catalyst and corrects the target air-fuel ratio. This control enables preferential OSA consumption in the front-stage catalyst while retaining OSA in the rear-stage catalyst.

Vehicle test results confirmed that the proposed control reduced both HC and NO_x emissions compared with the conventional control. In addition, emission dispersion caused by catalyst temperature, motor driving time, and pre-restart air-fuel ratio history was reduced because the feedback control corrected the target air-fuel ratio according to the actual catalyst state. These results show that OSA state feedback control using an intermediate O₂ sensor is an effective approach for further emission reduction during engine restart in 100% electric drive HEVs.

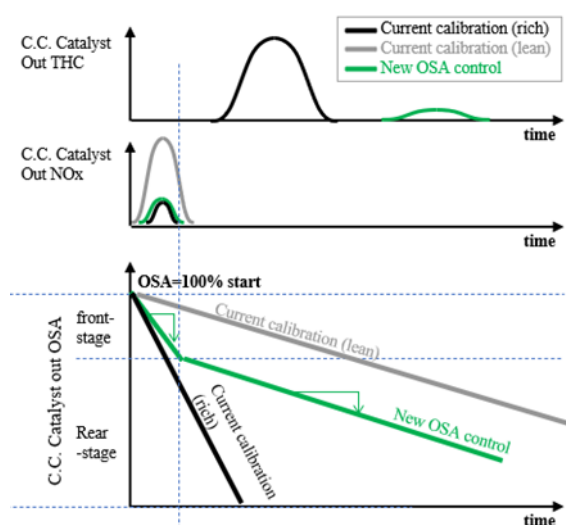


Fig.1 Concept of Catalyst OSA Control for HC and NO_x Reduction during Engine Restart

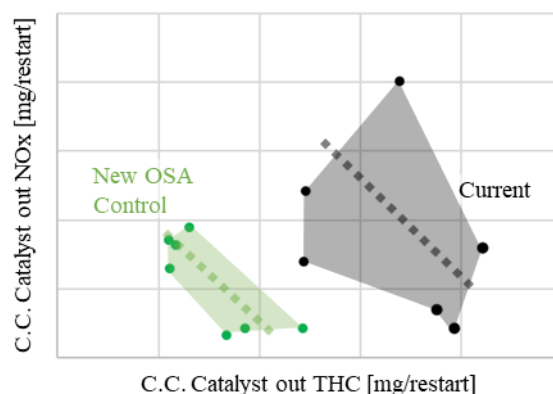


Fig.2 Improvement of HC-NO_x Trade-off by New OSA Control