Comparison of solid ammonium SCR system and urea SCR system in a 2.5L diesel engine

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Abstract

Solid ammonium SCR system has been investigated to reduce NOx emission from diesel engine. Solid ammoniums such as ammonium carbamate and ammonium carbonate have 2~3 times higher ammonia storage density than 32.5% urea solution. The solid ammoniums are decomposed into ammonia gas before injection. The ammonia gas injection is helpful to mixing and NOx reduction at low temperature. The solid ammonium SCR system is developed to control generation and dosing rates of ammonia gas. The solid SCR system consists of reactor, heater, dosing module and controller. Compact dosing module is developed including sensors, a regulator and an injector. Heating time and energy are reduced by the compact dosing module. Ammonium carbamate is used as an ammonia carrier. 6 bar of reactor pressure and over 100°C of dosing module temperature are required to inject ammonia and prevent solidification. At cold start, the reactor pressure and the dosing module temperature are reached within 180s. Decomposition rate of ammonium carbamate is measured depending on electrical power input. The solid SCR system is tested using a 2.5L engine at European stationary cycle (ESC). NOx conversions of the solid ammonium SCR system and urea SCR system are compared. The solid ammonium SCR system is also tested when SCR catalyst temperature is under 200°C. Urea injection is unavailable under 200°C because of solid deposit formation. The low temperature operation of SCR system could reduce NOx emission during urban driving.

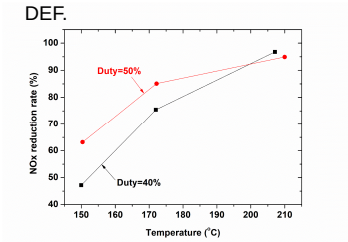
Introduction

▣ Urea SCR system

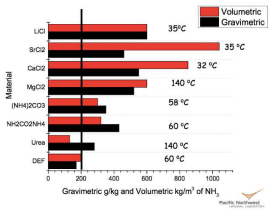
- Urea SCR system is widely used to meet EURO-6 standard. However, DEF injection is limited under 200°C because of solid deposit formation.
- Ammonia gas injection, burner, Heated DEF dosing, etc. are promising technologies to reduce NOx emission under 200°C.

▣ Advantages of solid ammonium SCR system

- Ammonia gas injection improves NOx reduction rate under 200°C.
- Mixer can be minimized by ammonia gas injection.
- Solid ammonium has 2~3 times higher ammonia storage density than DEF.



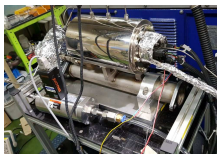
[NOx reduction rate of solid ammonium SCR system]



[Ammonia storage density[1)]]

[1)] DOE AMR Review, Next Generation SCR-Dosing System Investigation, 2016

Experiments



[Solid ammonium SCR system]

NRTC result of Solid ammonium SCR system (HOT mode)				
	CO (g/kWh)	NMHC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Tier-4	<5.0	<0.10	<0.4	0.02
Eng. Out	2.415	0.466	3.617	0.016
Tailpipe	0.009	0.003	0.208 (94%)	

▣ Solid ammonium SCR system

- Solid ammonium SCR system consists of dosing module, reactor, exhaust gas recirculation blower and controller.
- In the previous research, tier-4 emission standard was meet with 3.4L diesel engine and reactor type 2 at NRTC HOT mode.

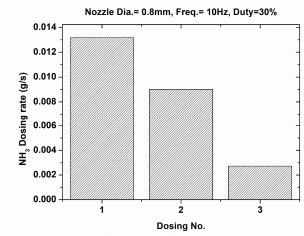
[Images of the engine used in this study]

Engine specification of engine used in this study	
Engine Displacement(L)	3.9
Compression ratio	17
Max. power(ps/rpm)	150/2500
Emissions standard	EURO-5 (NOx <2.0 PM<0.02 @ND-13)
Fuel injection system	Common rail

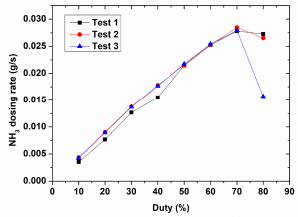
Results and Discussion

▣ Dosing module and dosing valve

- Compact dosing module was developed to reduce start-up time and energy consumption.
- Accuracy and precision of ammonia dosing rate were improved by the modification of dosing valve.



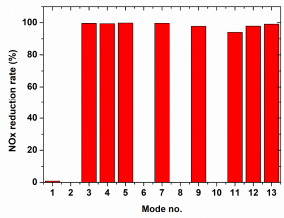
[NH_3 dosing rate of dosing valve ver. 2]



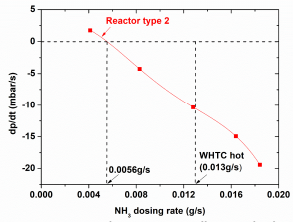
[NH_3 dosing rate of dosing valve ver. 3]

▣ NOx reduction rate and ammonia generation rate of reactor type 2

- NOx reduction rate was measured individually at each mode of ESC.
- NOx reduction rate was 94%~97% at mode No. 3~5, 7, 9 and 11~13.
- However, the required amount of ammonia was higher than ammonia generation rate at mode No. 2, 6, 8 and 10.
- 3 times higher ammonia generation rate is required for WHTC of the 3.9L diesel engine.



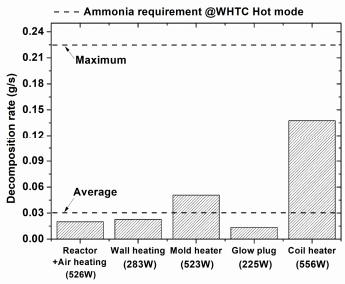
[NOx reduction rate at ESC]



[Reactor pressure change according to dosing rate]

▣ Reactor type 3 design for 3.9L diesel engine

- Coil heater is introduced to increase ammonia generation rate.
- Sub-reactor is designed for ammonia generation during the cold start.
- The reactor type 3 will be test in WHTC of 3.9L diesel engine.



[Solid ammonium decomposition rate]

Conclusion

1. Compact dosing module and dosing valve of solid ammonium SCR system were developed for accurate and precise ammonia dosing.
2. 94%~97% of NOx reduction rate was observed at mode No. 3~5, 7, 9 and 11~13 of ESC.
3. However, ammonia generation rate of reactor type 2 was insufficient at ESC of 3.9L diesel engine.
4. Reactor type 3 is designed for high ammonia generation rate and cold-start up. The reactor type 3 will be test in WHTC of 3.9L diesel engine.

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