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International Conference and Exhibition on Automobile Engineering
2015 Valencia, Spain

EFFECTS OF SCR SYSTEM ON NOx REDUCTION IN HEAVY DUTY DIESEL ENGINE FUELLED WITH DIESEL AND ALCOHOL BLENDS

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Introduction

- Diesel engine is one of the major reason of air pollution like hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM) and other toxic species.
- Diesel engine exhaust emissions consist mainly of high levels of nitrogen oxides (NOx), and its emission into the atmosphere is one of the main threats to the environment.
- Due to growing concerns about protecting the environment and human health, the NOx emission standards from heavy duty diesel engines have been continuously tightened over the years throughout the world.

Introduction

- Among the engine aftertreatment devices, a urea selective catalytic reduction (SCR) is one of the promising aftertreatment devices for the abatement of exhaust emissions, particularly for NO*x* pollutants. Relative to other alternative aftertreatment systems, the use of an SCR system can improve the economy of the engine together with the reduction of NO*x* emissions (Dieter et al., 2003).

Introduction

- It is called ‘Selective’ because it does not reduces the excess oxygen which is typical to a lean exhaust in a diesel engine.
- It involves mixing the exhaust air with a gaseous reagent, typically ammonia or urea, and passing the homogenous mixture over a bed of catalyst which causes the reaction to undergo completion at the air stream temperature.

Introduction

- The NH_3 selectively reacts with the NO_x component in the gas stream without reacting with the O_2 available in large excess.
- The catalyst promotes the reduction of NO_x with NH_3 in the presence of O_2 in the exhaust stream, forming nitrogen (N_2) and water (H_2O).

Introduction

- For enhance the quality of the performance and combustion various fuel additives are currently used in the automotive industry. The most investigated additives are oxygenated fuel additives in terms of diesel combustion and emissions
- Methanol, ethanol and butanol are preferred as fuels because they can be generated by fermentation of sugar from vegetable materials, like as corn, sugar cane, algae, and other plant materials compraising cellulose. Alcohol fuels have many advantages such as reduce particulate matter (PM), nitrogen oxides (NOx) and carbon monoxide (CO) emissions due to the additional oxygen in fuel.

Introduction

- The aim of this study was to investigate the effects of alcohol fuel blends on NOx emissions of diesel engine, equipped with SCR system to further reduce the NOx emission.

Experimental Set Up

- Exhaust emmission variations of diesel blends with alcohol additive was carried on a six cylinder, four-stroke, air-cooled turbocharger diesel engine with and without SCR system. A hydraulic dynamometer was used to determine the torque.

Experimental Set up

Table 1. The engine specifications

Brand	Cummins
Model	ISBE4+250B
Type	Electonic control system
Cylinder	6
Bore/Stroke	107/124 mm
Compression Ratio	17.3
Aftertreatment	SCR
Displacement	6700cc
Power	184 kW@2500 rpm
Torque	1020Nm @1500 rpm
Oil Cooler	Turbocharger & aftercooled

Experimental Set up

Table 2. Specifications of Dynamometer

Torque range	0-1700 Nm
Speed range	0-7500 rpm
Body weight	45 kgf
Total weight	110 kgf
Body diameter	350 mm
Torque arm length	350 mm

Experimental Set up

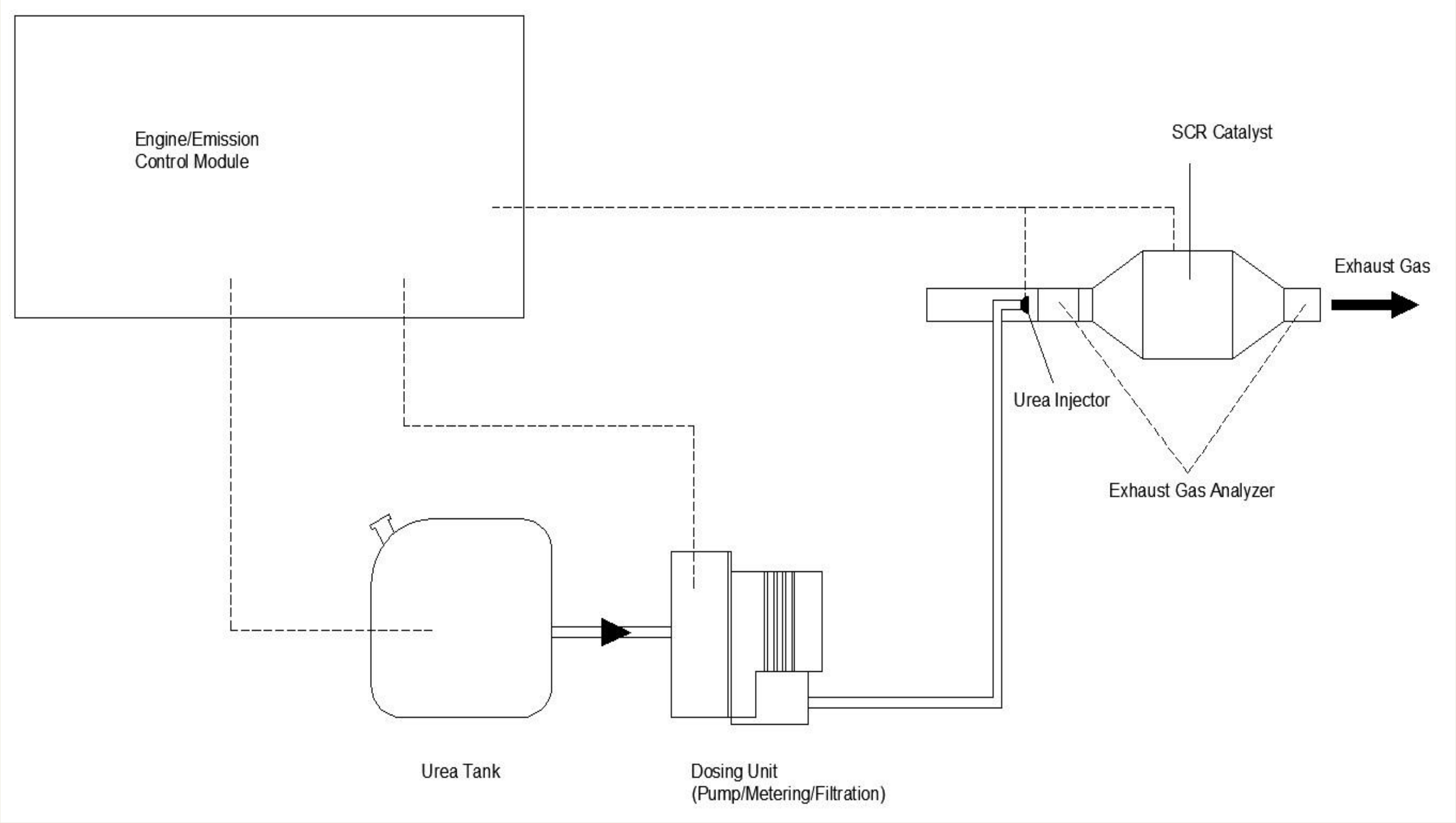

Figure 1. Shematic diagram of test unit

Experimental Set Up

- AVL SESAM i60 Fourier Transform Infrared Spectroscopy (FTIR) device was used measuring of exhaust emissions. The fuel blends were tested between 1400 rpm to 2400 rpm with interval of 200 rpm in full load conditions.

Experimental Set up

Table 3. AVL SESAM i60 Fourier Transform Infrared Spectroscopy (FTIR)

Sampling rate	1 scans per second (1 Hz)
Data rate	All measured gas components at 1 Hz
Spectral resolution	0.5 cm-1
Measurement cell	Gas cell heated to 191°C
Response time	t10 to t90 within 1 s (fast response version within 300 ms)
Sample flow rate	10 l/min per stream (20 l/min for fast response version)
Detector cooling	Liquid nitrogen 50ml/h
Zero/purge gas	Nitrogen/synthetic air. 0.6-1.5l/min
Compressed air	5-6 bar rel. Max. 100l/min per FTIR stream

Experimental Set up

Table 4. Specifications of the Aqueous Urea for SCR

Name	Aqueous Urea Solution
Chemical Formul	$(NH_2)_2CO.H_2O$
Molecular weight	60.06 g/mol
Urea Concentration in solution	32.5%
Density @ 20ºC	1.089 g/cm^3
RI @ 20˚C	1.3828
pH value	9-11
Appearance	Colorless
Cristallization Temperature	-11 ºC
Alkalinity as NH_3	0.0002

Experimental Set up

Table 5. Specifications of the catalyst in Aftertreatment system

	SCR
Diameter (m)	0.2667
Length (m)	0.3048
Cell Geometry	Honeycomb type square celled catalyst
Total Volume (L)	17
Cell Density/in^2	400
Wall Thickness (mm)	0.105

Preparation of Fuel Blends

- The fuels used in the experiments are diesel, methanol, ethanol and butanol.
- The fuel blends were prepared by mixing euro diesel at volumetric rates of 5, 10 and 15%.
- Methanol-diesel blends specified as D95M5, D90M10 and D85M15.
- Ethanol-diesel blends specified as D95E5, D90E10 and D85E15.
- Butanol-diesel blends specified as D95B5, D90B10 and D85B15.

Preparation of Fuel Blends

Table 6. Fuel Properties of diesel, methanol, ethanol and butanol

Fuel Properties	Diesel	Ethanol	Methanol	Butanol
Density (kg/lt)	0.833	0.788	0.793	0.810
Cetane Number	61	~8	3.8	~25
Viscosity (cSt)	2.7	1.078	0.5445	3.6
CalorificValue (kj/kg)	45,100	26,900	20,100	33,100
Boiling Point	180-360	78	64	118
Stoichiometric air fuel ratio	15	8.9	6.7	11.2

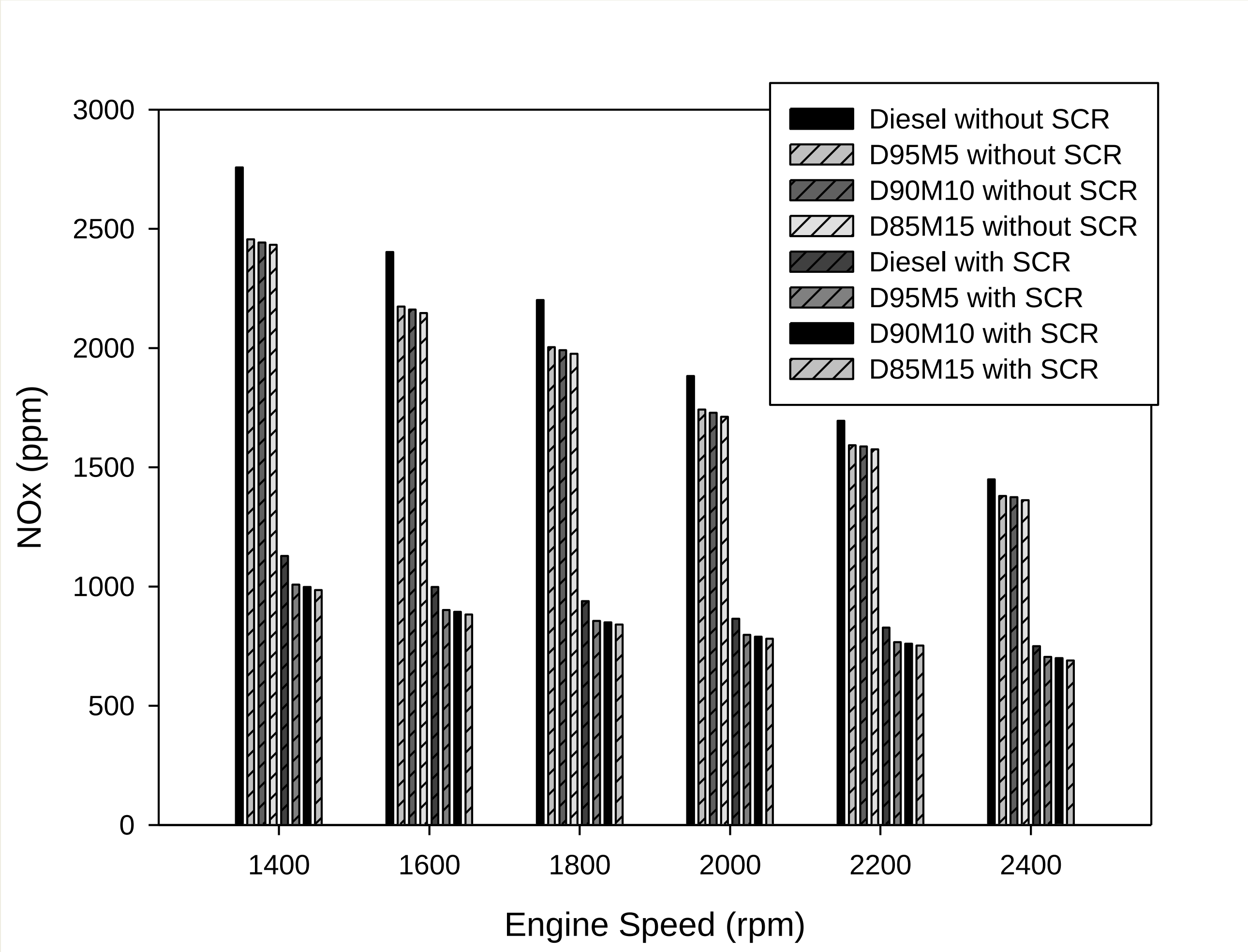

Figure 2. Investigation of (a) NOX (oxides of nitrogen) emission

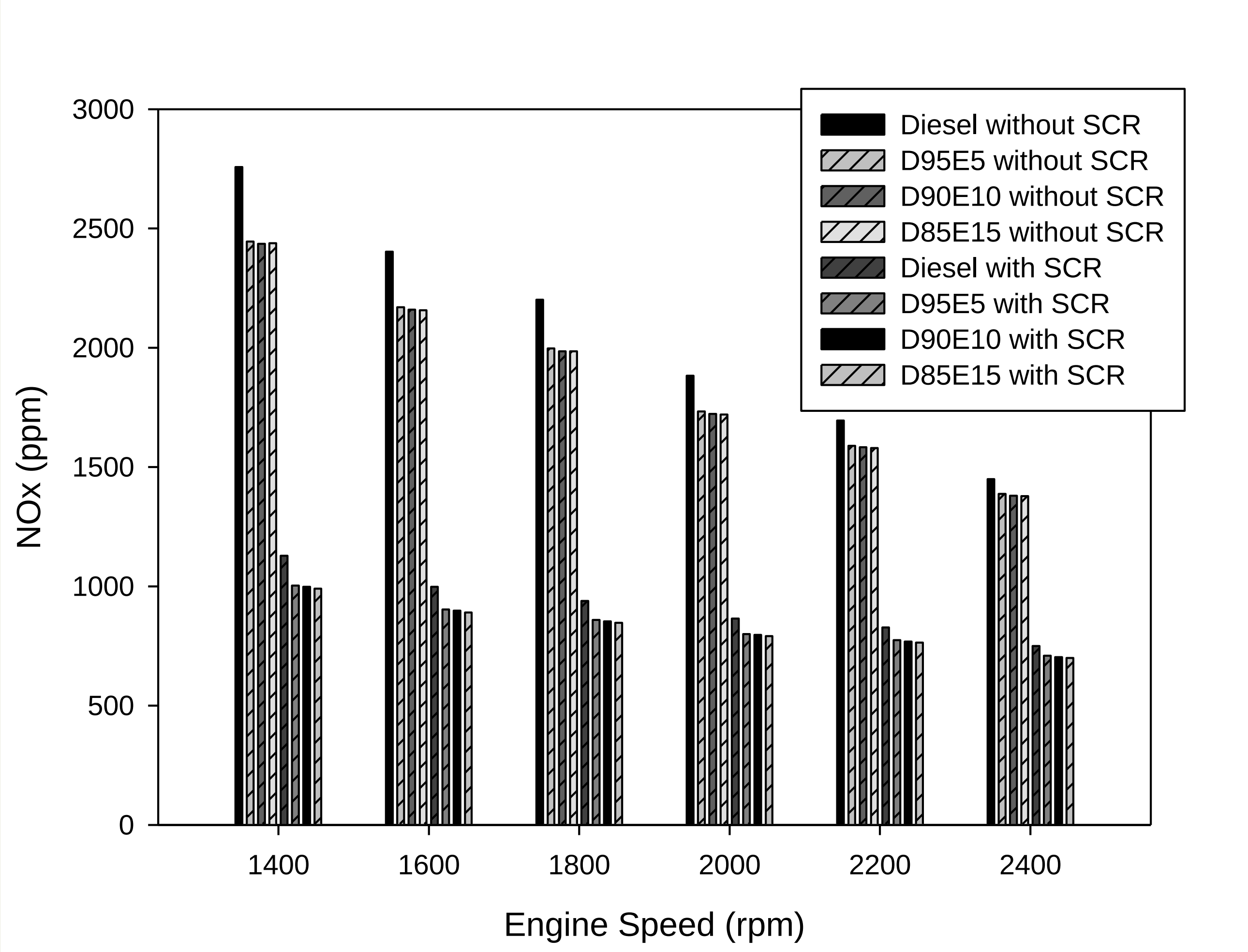

Figure 3. Investigation of (a) NOX (oxides of nitrogen) emission

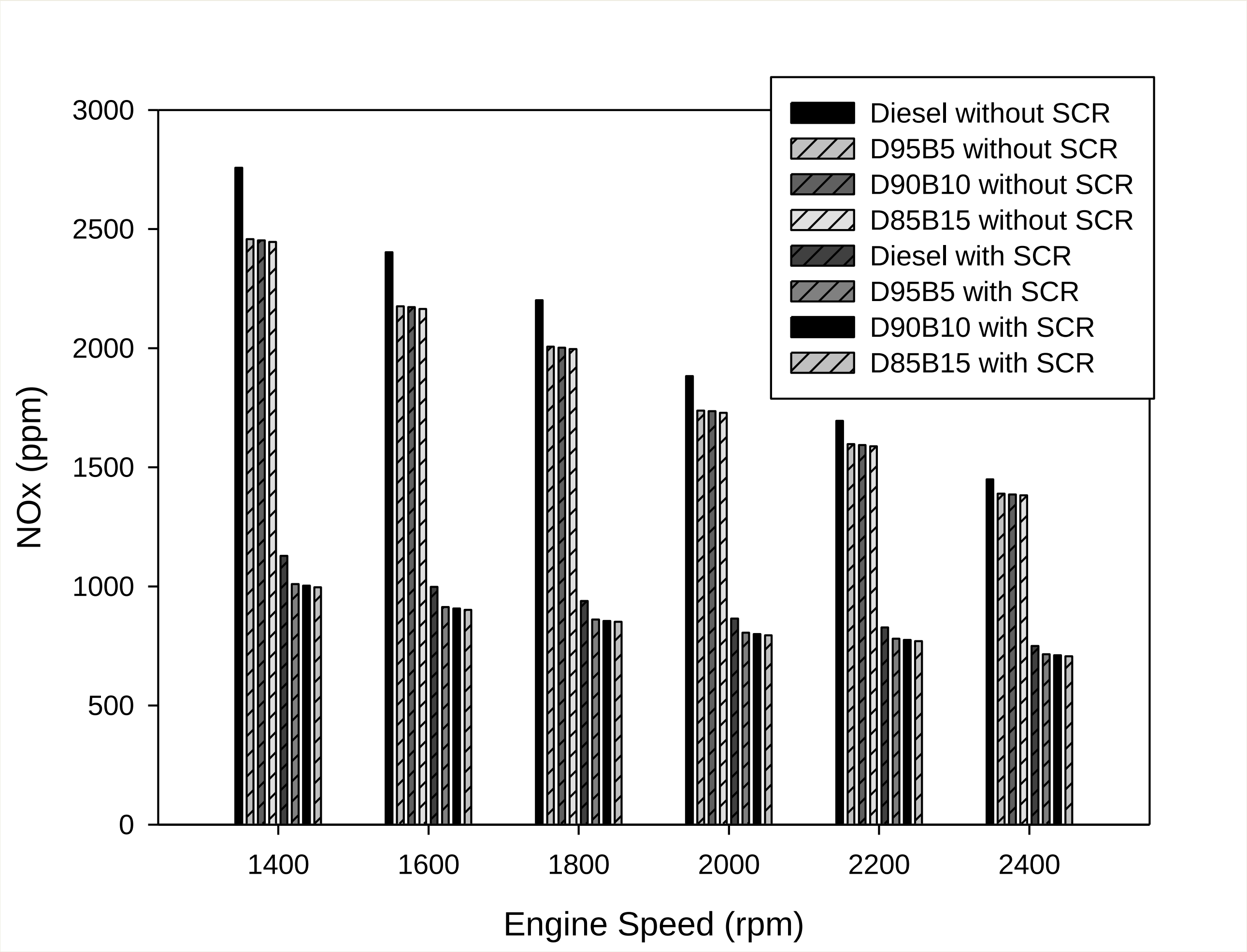

Figure 4. Investigation of (a) NOX (oxides of nitrogen) emission

NOx Emissions

- When urea is injected in the exhaust manifold, the breakdown of urea [(NH2)2CO] into ammonia happens by virtue of two processes thermolysis and hydrolysis as shown below,
  - $(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$
- Precisely, the ammonia formed during the decomposition and hydrolysis process reacts with NO and NO2 in the tail pipe to from N2 and H2O. The reaction which governs the formation of end products, after urea injection, is as follows,
  - $2NH_3 + NO + NO_2 \rightarrow 3H_2O$
- Similar findings were reported by many researchers when using urea based SCR systems, emphasizing it as one of the prominent method to reduce NOX emission (Birkhold et al., 2006; Koebel et al., 2000).

Conclusion

- Addition of ethanol, methanol and butanol decrease the NOx emissions with respect to neat diesel. The reason of the reduction may be due to the increasing oxygen content and lower cetane number of alcohol additives. Lower cetane number of ethanol, methanol and butanol blends precipitates to longer ignition delay, and leading possibly to higher combustion temperature during the premixed combustion mode.

Conclusion

- The maximum reduction for diesel with the addition of SCR is 59%.
- The average reduction in NOx for SCR for D100, D85M15, D85E15 and D85B15 is 42.6%, 46.45%, 45.9% and 45.5% respectively as compared with diesel fuel at full load.

ACKNOWLEDGEMENT

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Thank You For Your Attention