7th ETH Conference on Combustion Generated Particles

Title:
Particulate Emissions Characterization and Combustion Analysis by using Water-Diesel Fuel Emulsions in Heavy Duty DI-Diesel Engines equipped with Common-Rail Injection System

Authors & Affiliation:
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Urs Mathis, Martin Mohr; EMPA, Combustion Engines / Furnaces

Abstract:
Measurements are carried out on a heavy-duty four-cylinder diesel engine equipped with turbocharger and common rail fuel injection. The engine investigations are conducted in different operating points in the engine map covering wide load ranges and EGR rates. The injection parameters are thereby set independently. Experiments are conducted with reference diesel fuel and 3 different water-in-diesel-emulsions (13% / 21% / 30% Water). In this contribution we present the impact of engine and fuel technology on the combustion process and on the nanoparticle emissions.

By using diesel-in-water-emulsions particulates and NOx are reduced in a significant way (e.g. at the operating point A25, for the 30% emulsion compared to diesel fuel, we measured 30% NOx and 70% PM reduction). The combustion flame temperature decreases linearly with the added water amount in the fuel, its major effect is on NOx reduction. Lower particulate emissions are due to lower soot formation for the water-diesel fuel emulsions (e.g. improved mixing of the fuel with the combustion air).

The fuel consumption (diesel equivalent) when using diesel-in-water-emulsions is similar to that of the reference fuel.

The number and size of the emitted particles is very sensitive to the added water quantity in the fuel. When using diesel-water emulsion fuels the mean particle diameter of the accumulation mode decreases and, at low load conditions, a nucleation mode is present. The majority of these ultrafine particles could be removed using a thermodesorber, indicating the presence of condensates. The rest of the particles in the size range under 20-30 nm seem to be solid particles (maybe salts or ashes); these are only present when the number of particles in the accumulation mode is very low.

The combination diesel-in-water-emulsions and EGR is very effective to reach lowest NOx and particulate emissions values (but the fulfillment of EUROIV still does not appear to be possible).

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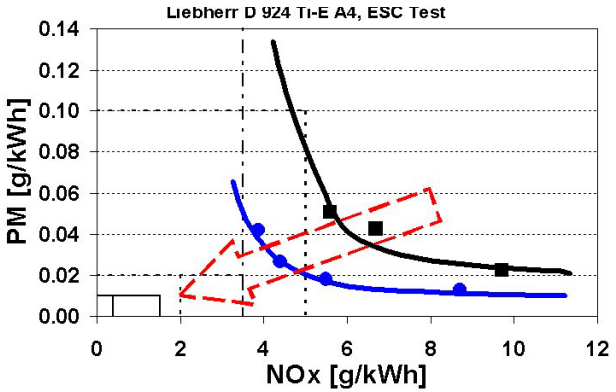
Background & Research Approach

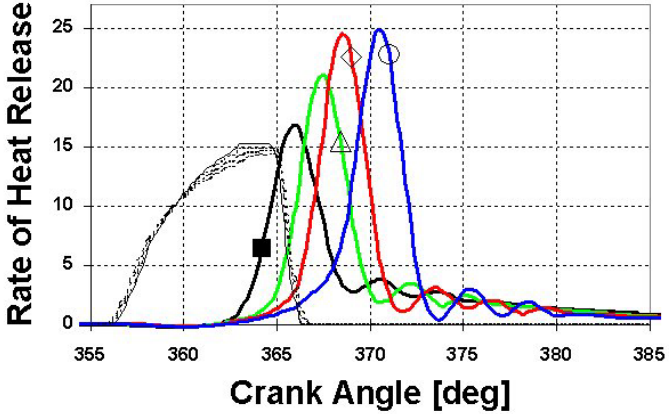
Research project

Technologies for lowest NOx and particulate emissions in DI-diesel engine combustion – influence of injection parameters, EGR and fuel composition

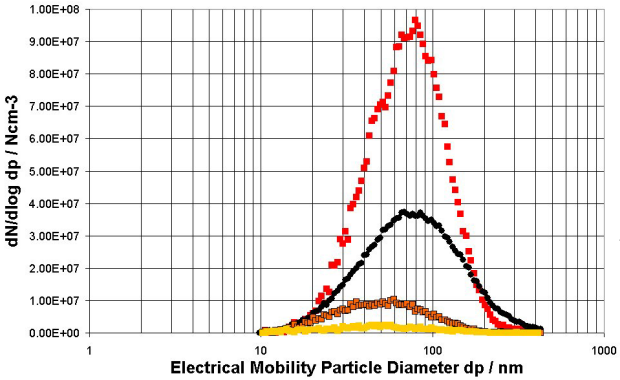
Engine performance & emissions



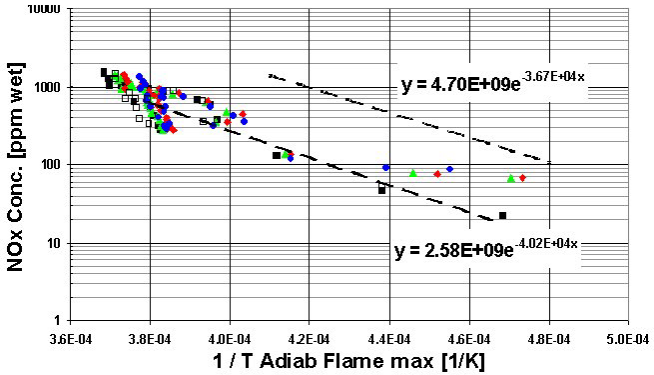
Combustion analysis



Particulate emissions



Correlations & modeling



Objectives

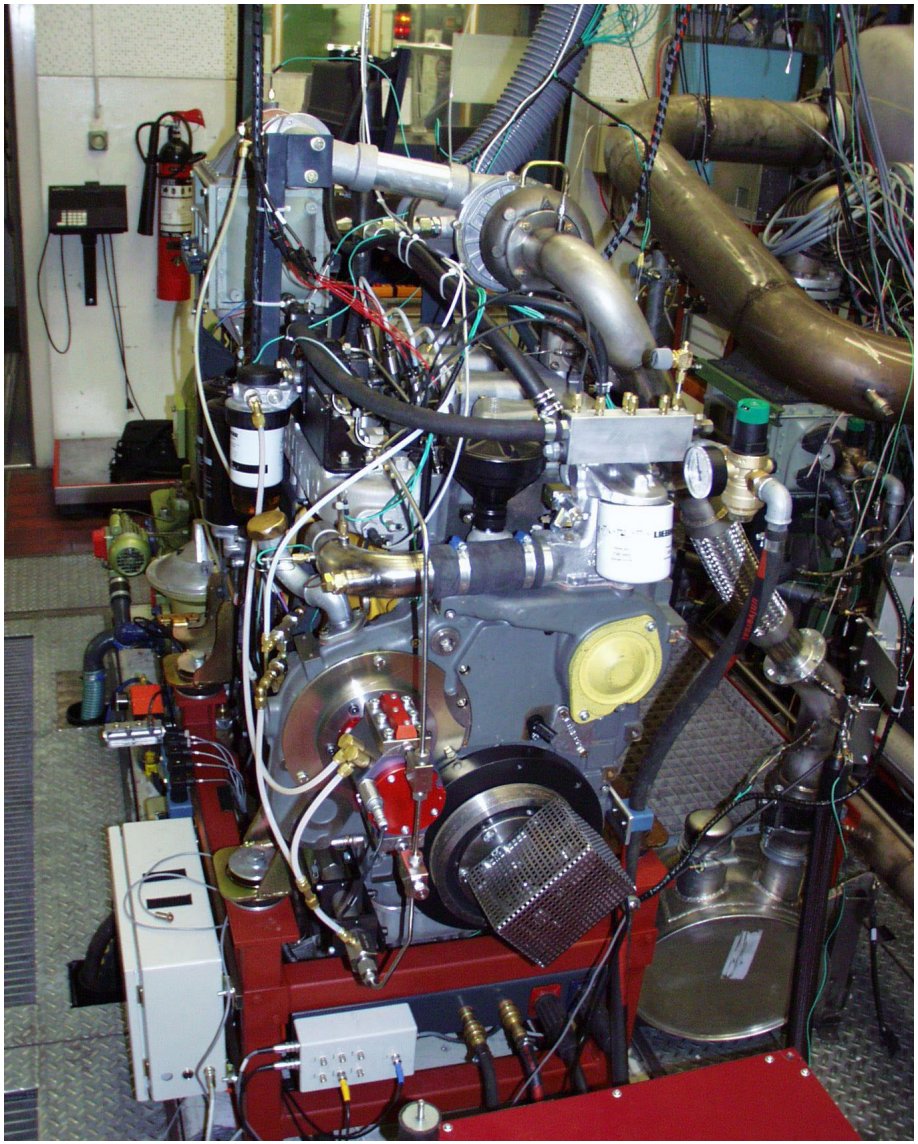
Effects of water-diesel fuel emulsions on NOx, particulates and relevant combustion parameters

Influence of water content in the emulsions

Combination of w-d emulsions with EGR

Combination of w-d emulsions with modern fuel injection system

Test Engine at LAV



- **LIEBHERR 4-Cylinder 4-stroke direct injected diesel engine**
  - Stroke= 142 mm; Bore 122 mm
  - V_e = 6.64 l ; ε=17.2
  - 183 kW @ 2100 1/min
  - 1060 Nm @ 1540 1/min
- **Common Rail Injection System**
  - ETH Fuel Pump (-2000 bar)
  - BSG Electronic (pilot & post injection)
  - CRT Injectors (-1600 bar), Type P2
  - Nozzle tip 8*0.200 mm
- **Turbocharger**
  - K 27.2 – 15.22
- **EGR-System (preliminar)**
  - Cooled EGR (high pressure side)
  - with Throttle after Turbine

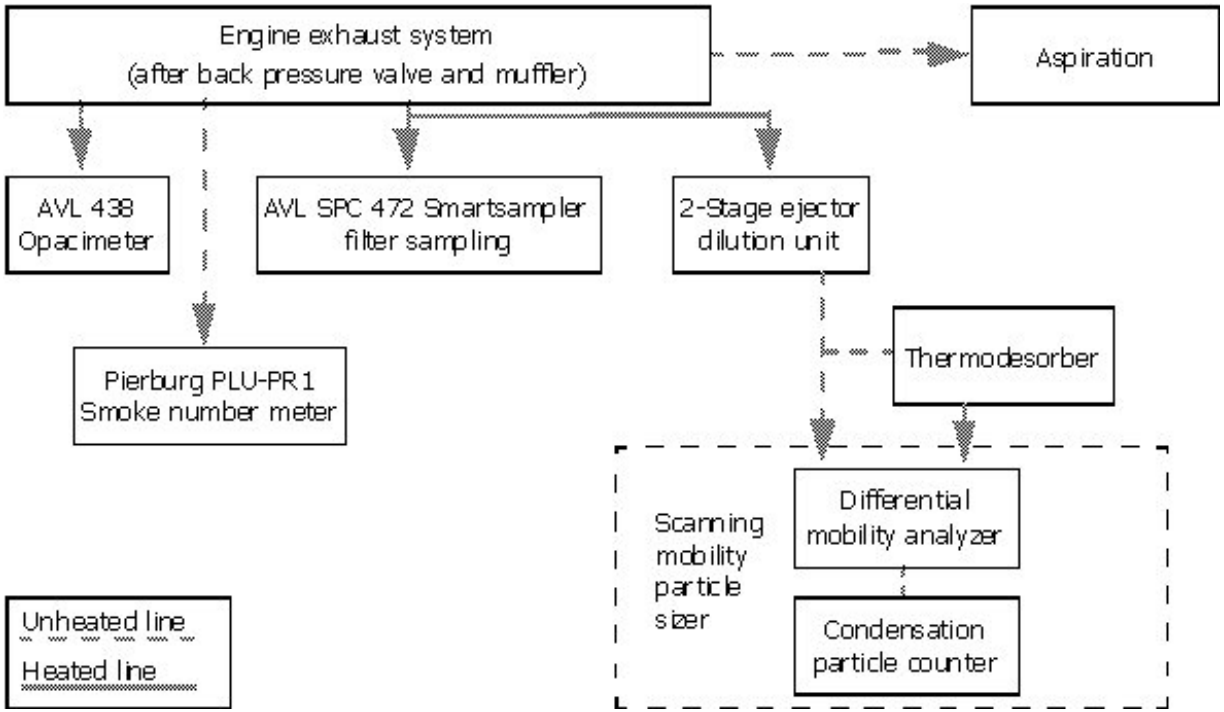
Parameter Variation

- Engine operating condition
  - Engine load
    A25, A50, A75, A100
- Fuel injection
  - Injection pressure
    500 – 1600 bar
  - Start of injection
    14°CA BTDC – 5°CA ATDC
- Air management
  - EGR rate
    0 – 42%
- Fuel compostition

Main properties of the fuels tested

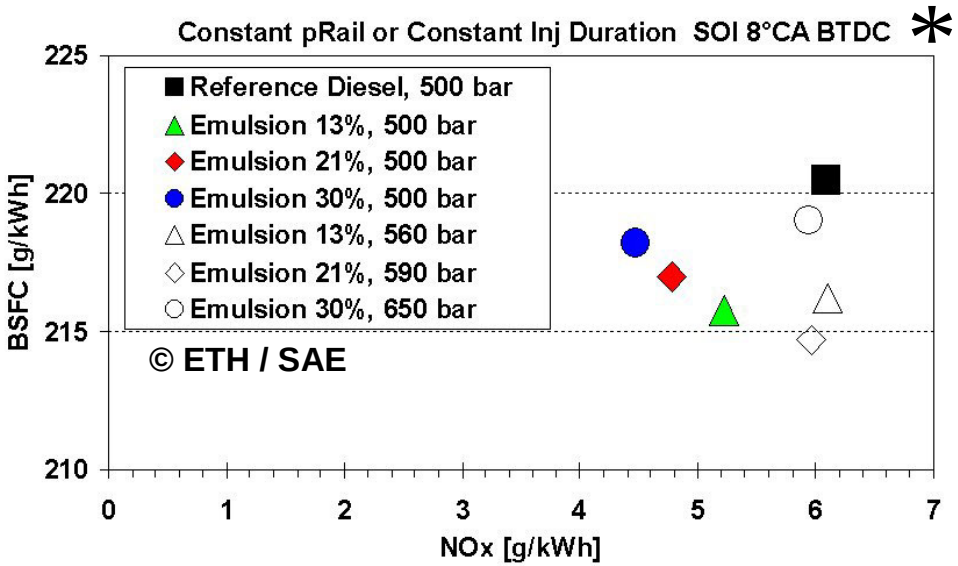
	Water content mW/(mD+mA)	Lower heating value	Density	Air/fuel ratio
	[%]	[MJ/kg]	[kg/m3]	[-]
Diesel	**0**	**43**	**820**	**14.6**
13% W-D emulsion	**13**	**38**	**850**	**13.0**
21% W-D emulsion	**21**	**35**	**860**	**12.4**
30% W-D emulsion	**30**	**33**	**870**	**11.8**

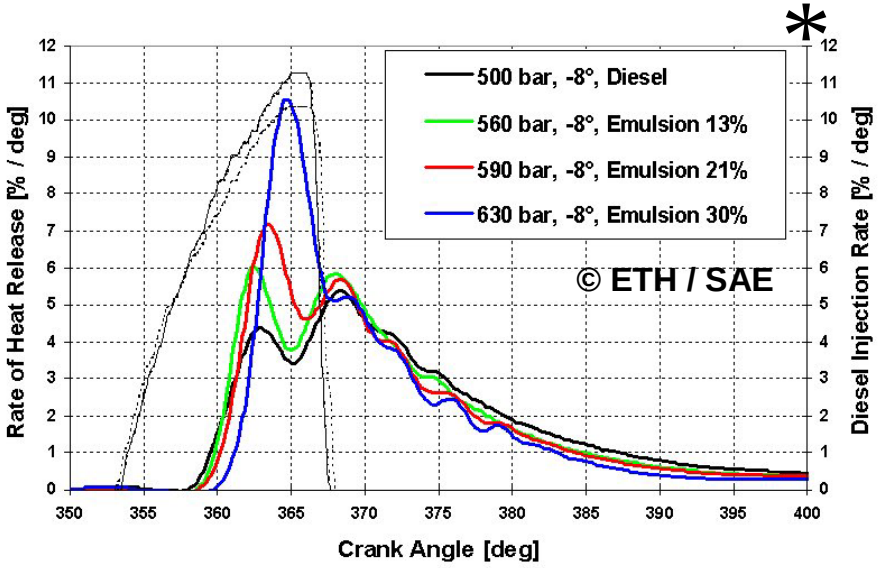
Measurement Setup Particulate Emissions

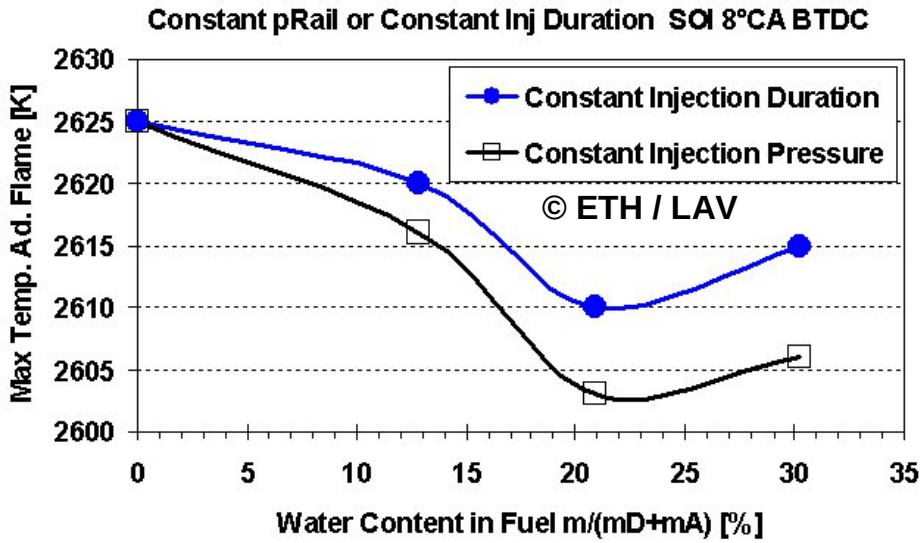


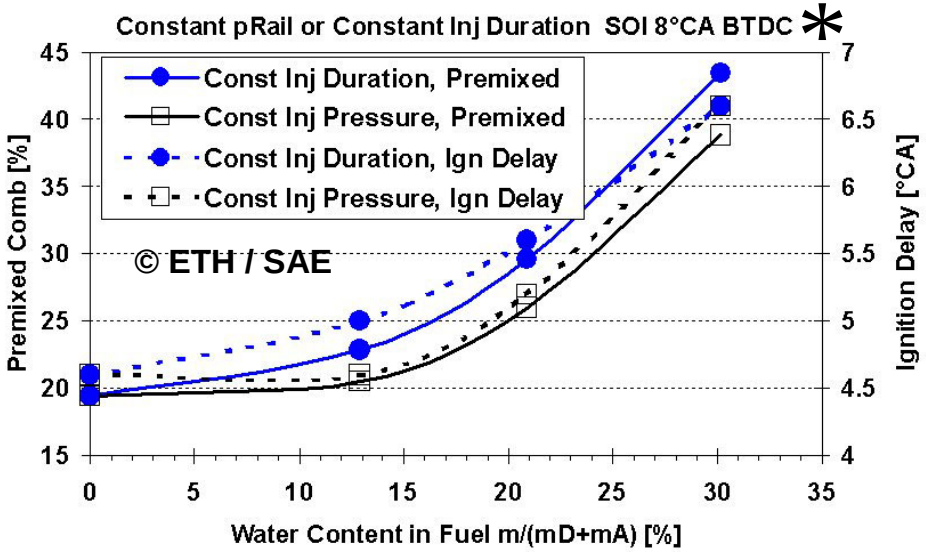
- Temperatures
  - Sample line from engine exhaust to dilution unit 170°C
  - Dilution air of the first ejector 150°C
  - Thermodesorber 350°C
- Dilution ratio ca. 124
- SMPS size range 9.82 – 429 nm
- Number of scans 2 - 15

W-D Fuel Emulsions, A25: Water Content Variation

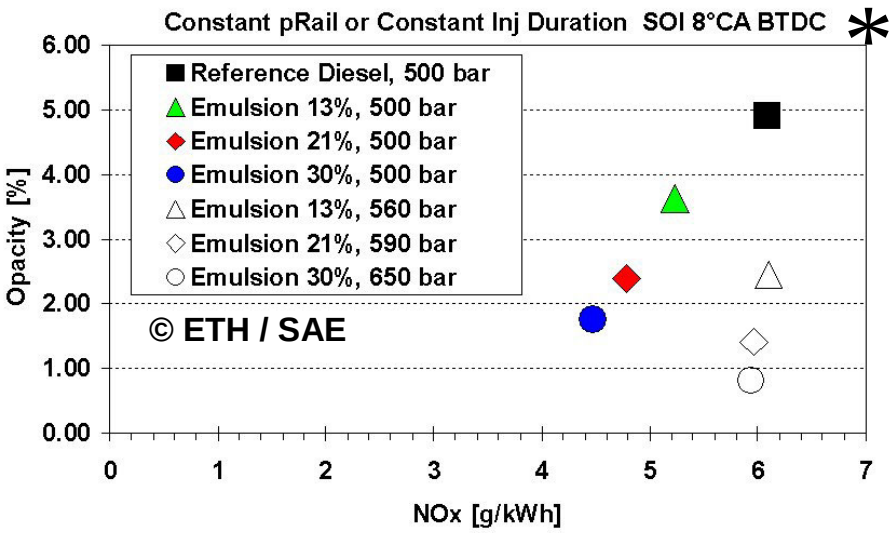


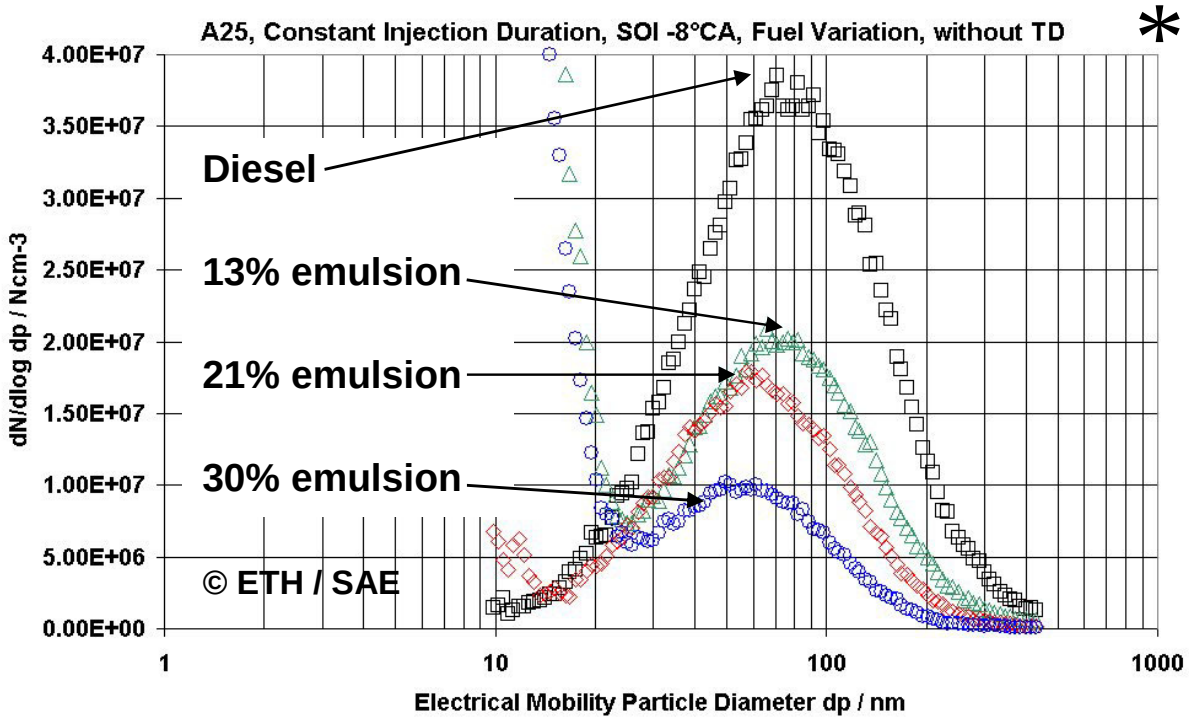




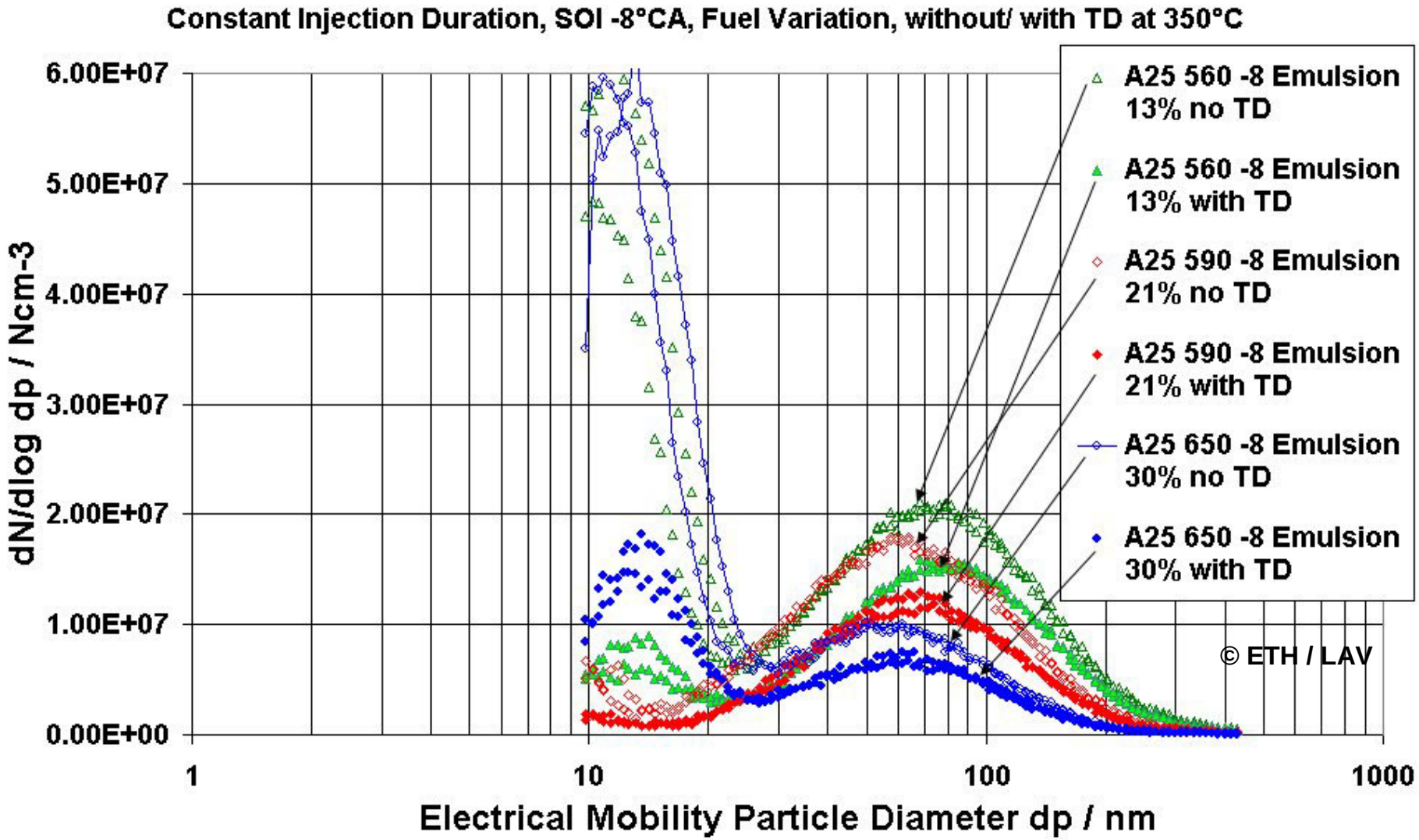


W-D Fuel Emulsions, A25: Water Content Variation

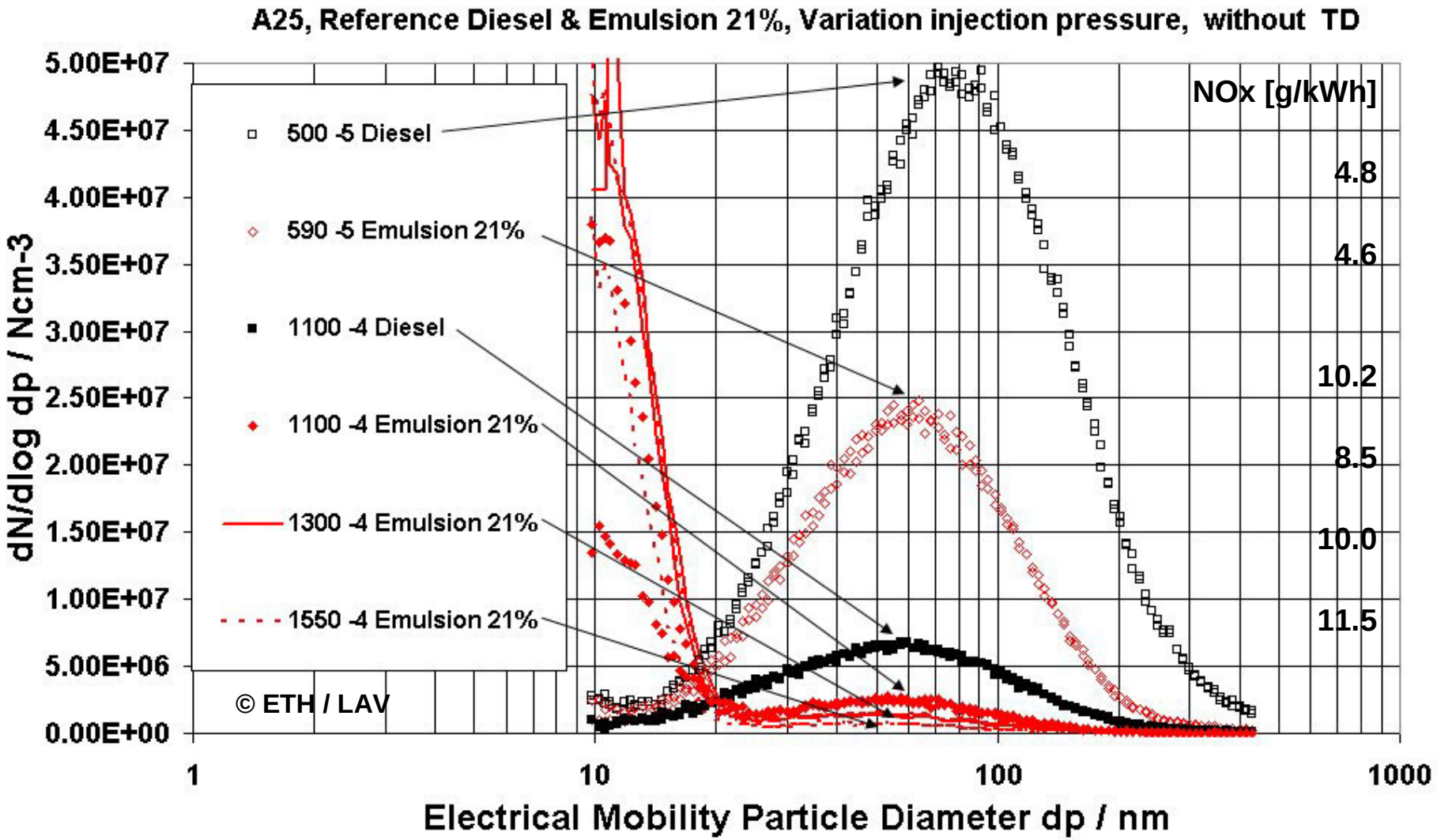




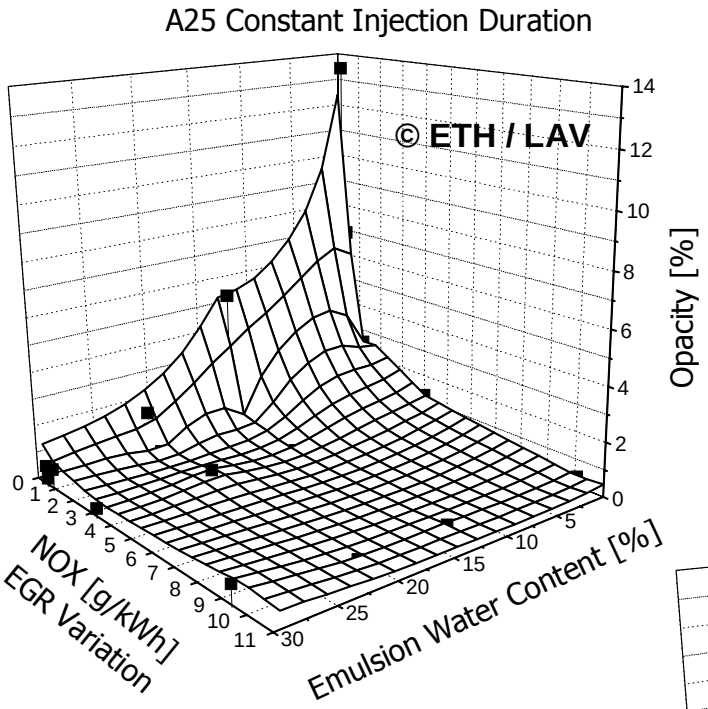
W-D Fuel Emulsions, A25: Influence of Thermodesorber

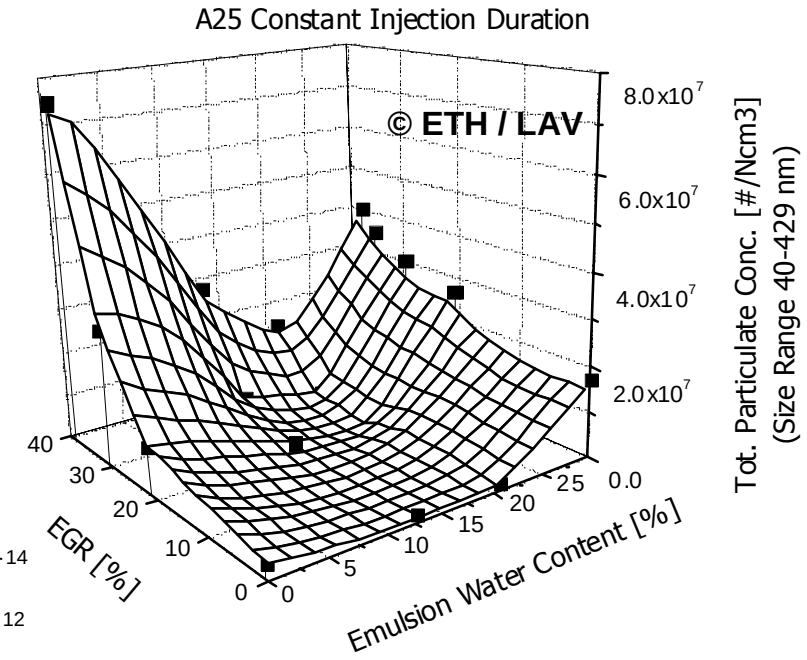


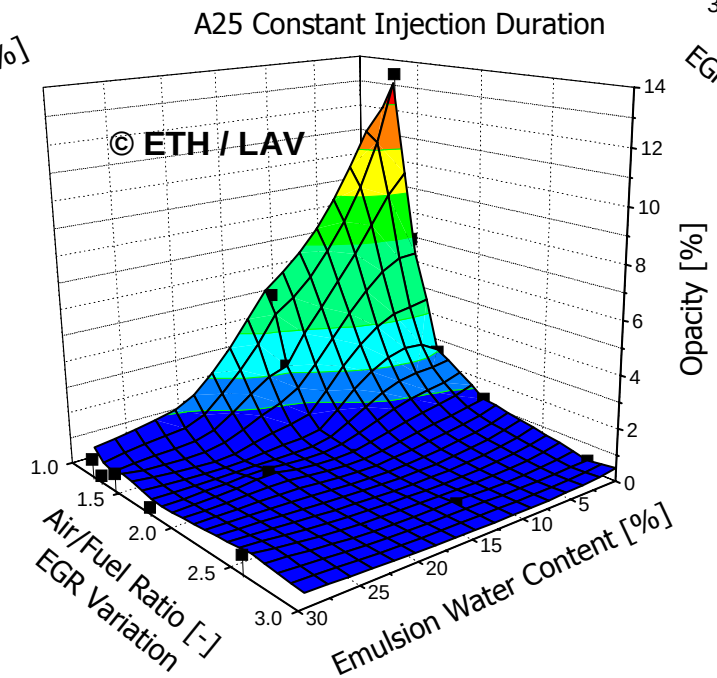
W-D Fuel Emulsions: A25 Injection Pressure Variation



W-D Fuel Emulsions, A25: cooled EGR







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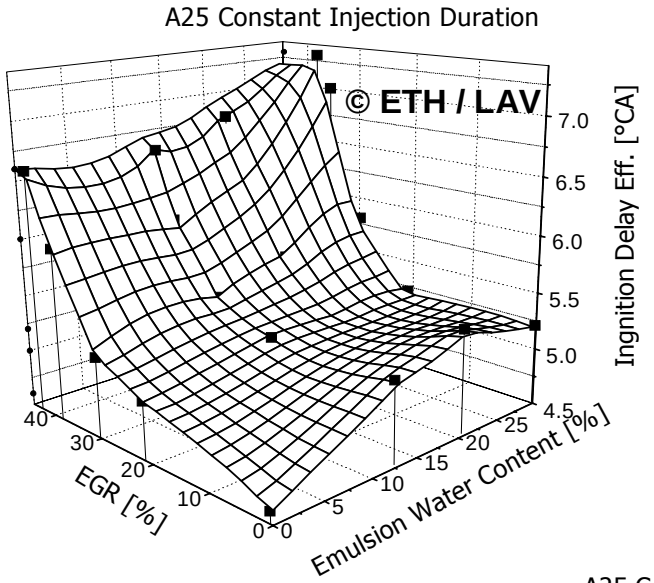
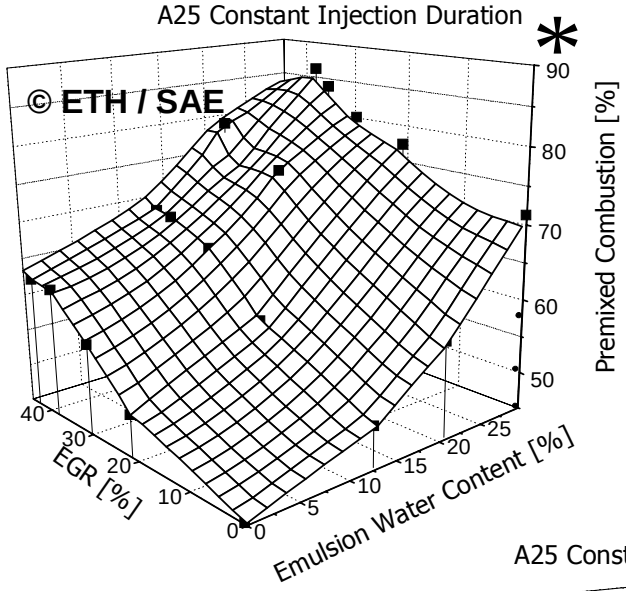
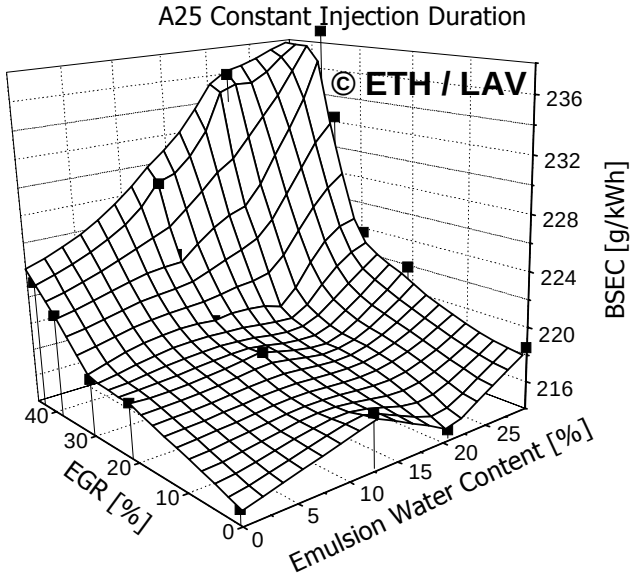
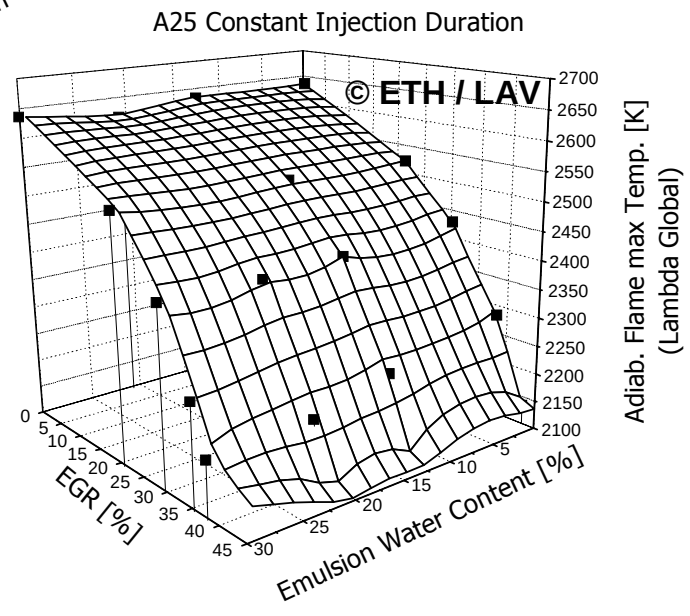
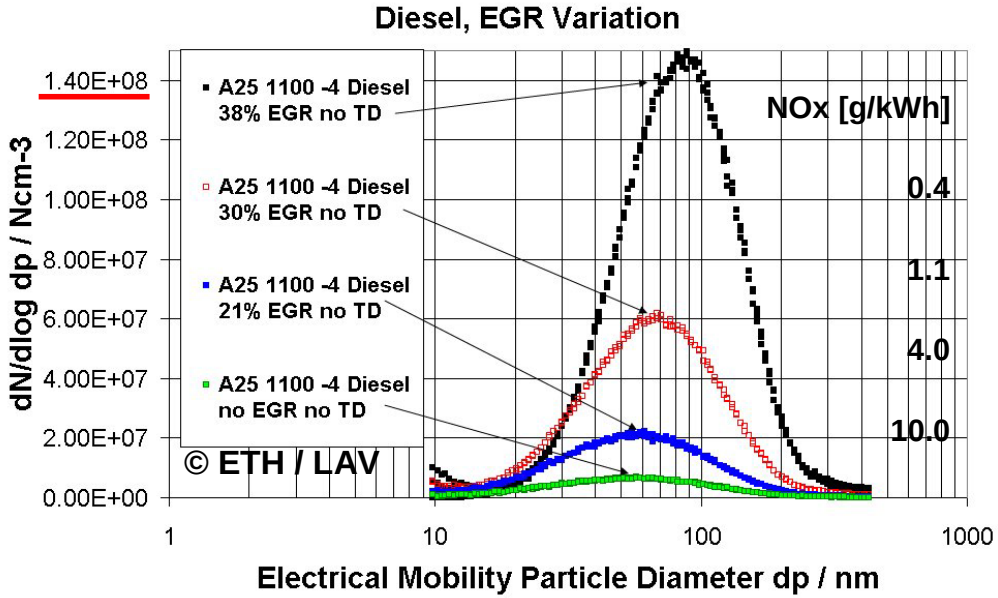


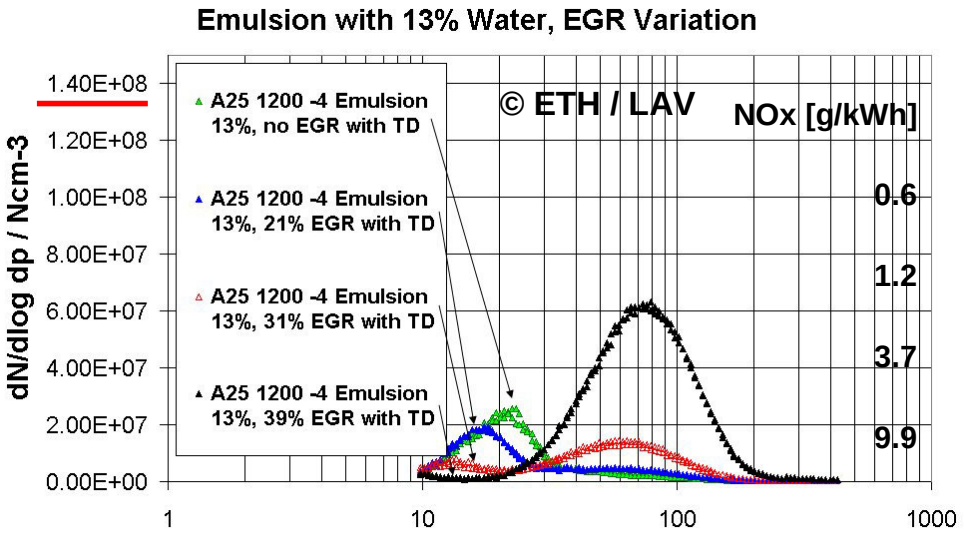


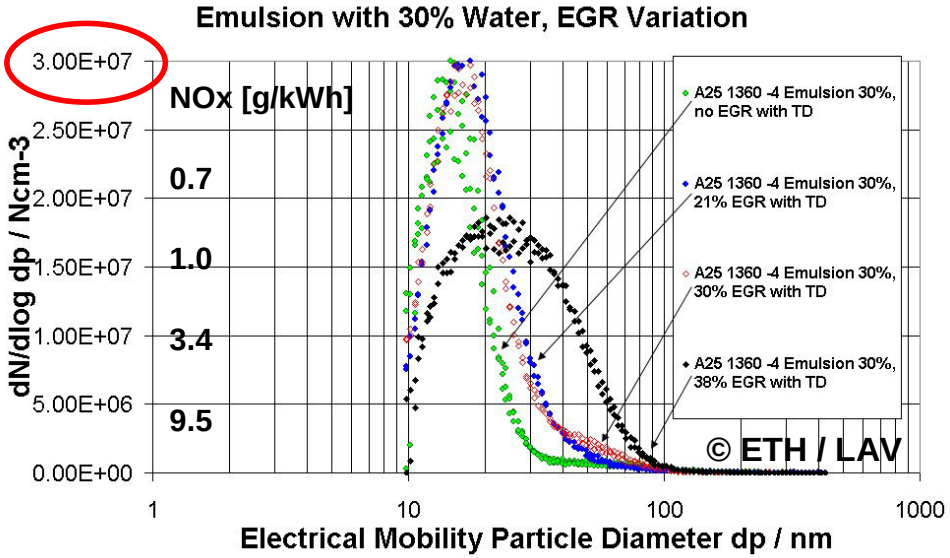




W-D Fuel Emulsions, A25: cooled EGR







Conclusions

Main effects of water-diesel fuel emulsions:

BSFC similar
NOx equal or lower
Ignition delay and premixed combustion higher
Combustion temperature lower, major effect on NOx reduction, no PM increase
Total number of particles (D > 50nm) lower
Mode particle diameter smaller
Accumulation mode always reduced
Nucleation mode present at:

- low or medium engine load
- high injection pressure
- moderate EGR rate
- high added water amounts

Nucleation mode eliminated in most cases by using a thermodesorber
By combining d-w fuel emulsions, cooled EGR and high injection pressure, lowest NOx and particulate emissions can be achieved

* SAE Powertrain & Fluid Systems Conference & Exhibition, October 28 – 30 2003, Pittsburgh, Pennsylvania USA
paper presentation Bertola et al: SAE 2003-01-3146

Acknowledgements

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