CCGEx

Competence Center Gas Exchange – KTH

CCGEx 2015 Research Day

Exhaust Aftertreatment

2015-11-12

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Atomization and Mixing of Urea Water Solution

PROJECT CONTENT/SCOPE

- Investigation of the sensitivity of UWS droplets mixing to input data.
- Characterization of the exhaust gas flow and its influence on mixing properties and wall-film formation.
- Study (and improvement) of droplet evaporation and thermolysis models.
- Extend the current Droplet-Wall-interaction modelling framework to include water evaporation and deposit formation.

PROJECT RESULTS

- Sensitivity study of mixing to different injection conditions (spray characteristics and injection position).
- Sensitivity of mixing to exhaust gas flow-rate
- Effects of jet intermittency

FUTURE PLAN SHORT & LONG TERM:

- Extend investigation on sensitivity of final mixing with Detached Eddy Simulation
- Investigate the effect of pulsating exhaust gas inflow conditions
- Include chemical reactions and investigate their effect in the final mixing characteristics

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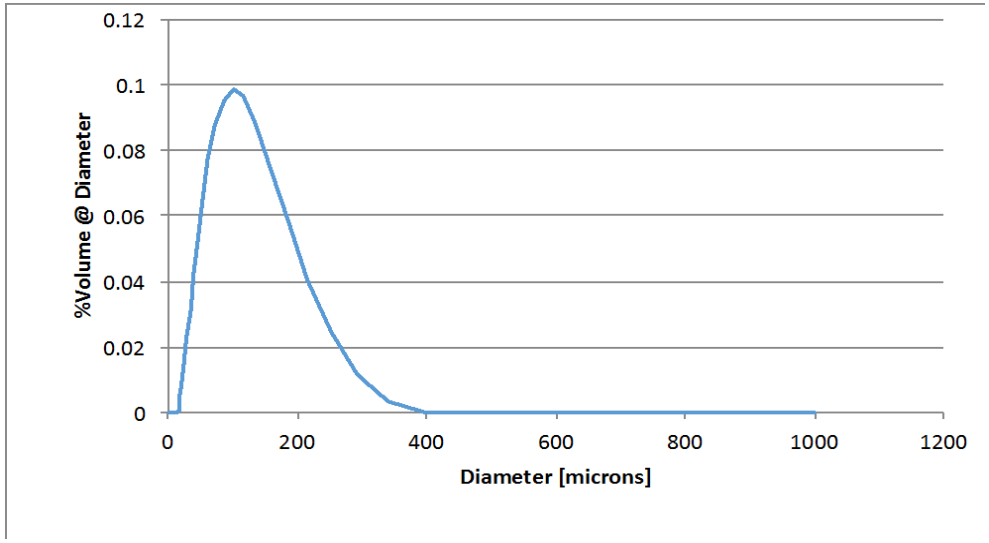
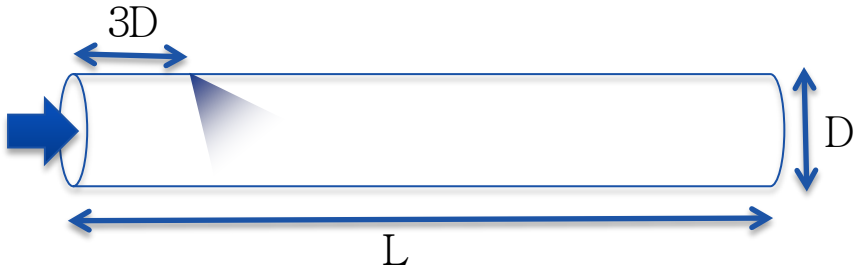
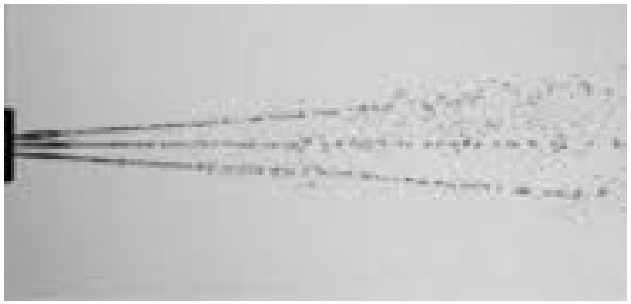
Simulation setup (VCC load point 6)

Exhaust gas		
Engine speed	2000	rpm
Torque	150	Nm
Exhaust mass flow rate	168	kg/h
Downstream SCR line backpressure (rel)	360	Pa
Diameter, D	65	mm
Length, L	15D	

UWS injection (3-hole; full cone)		
Mass flow rate	28.8	mg/s
Injection duration	5	ms
Injection amount per pulse	5.49	mg
Angle	30	°
Droplet velocity	22	m/s







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Simulation setup

Case	Injection angle	Type of injection	Gas flow
A	+45°	Intermittent	Steady
B	+45°	Continuous	Steady
C	-45°	Intermittent	Steady
D	-45°	Continuous	Steady
E	+45°	Intermittent	Pulsated
F	+45°	Continuous	Pulsated

Liquid Injection	
Frequency (Hz)	5 8 10
Duration (ms)	5

Gas flow	
Kg/h	110 168
Pulsation	±25%

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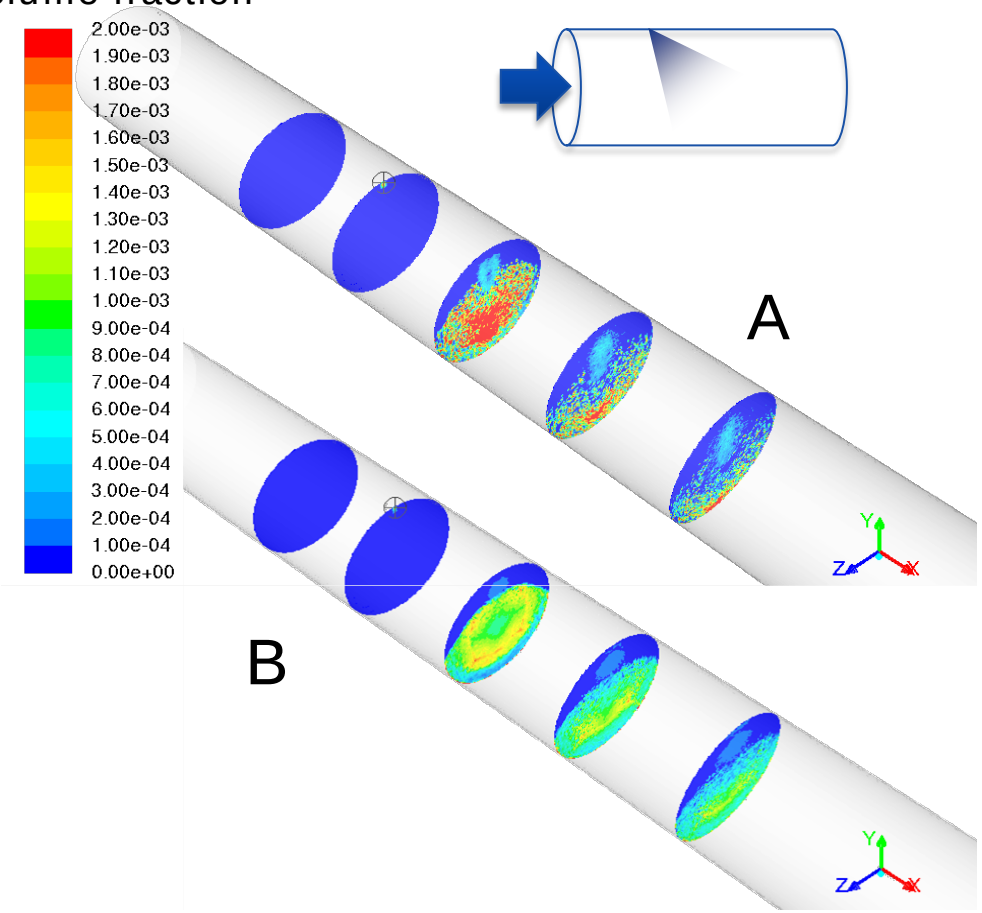
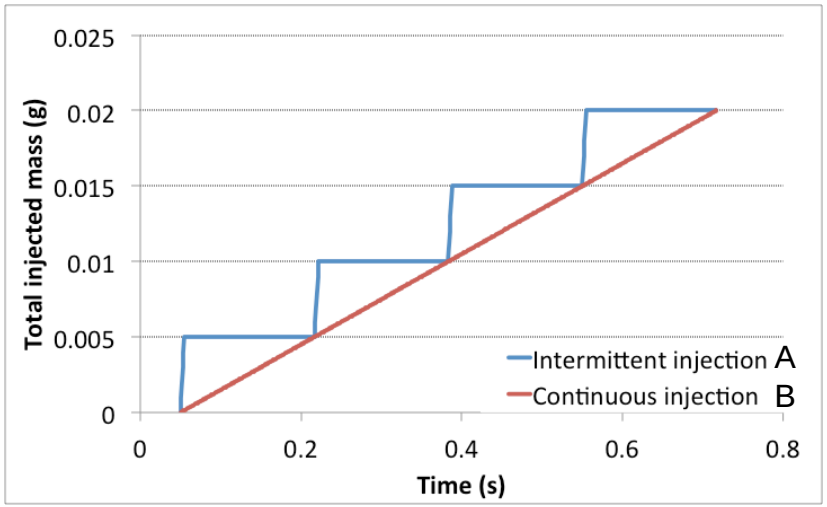
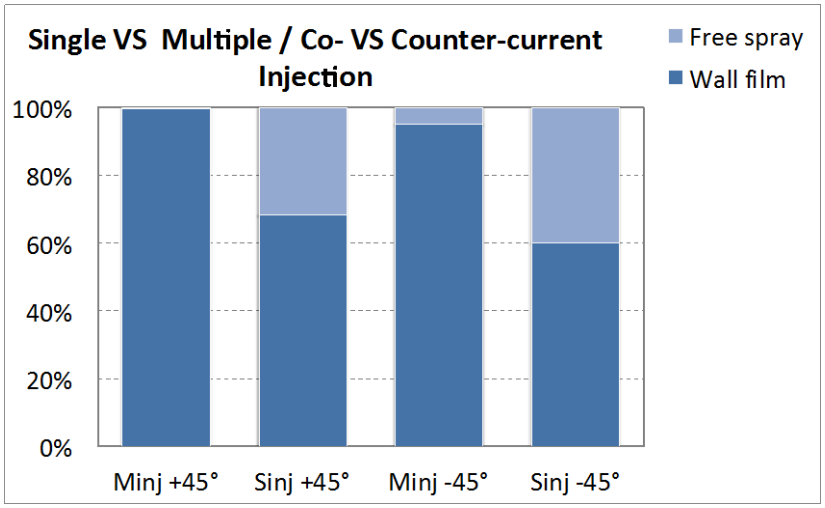
Results: Continuous VS Intermittent Injection

Mean droplet volume fraction







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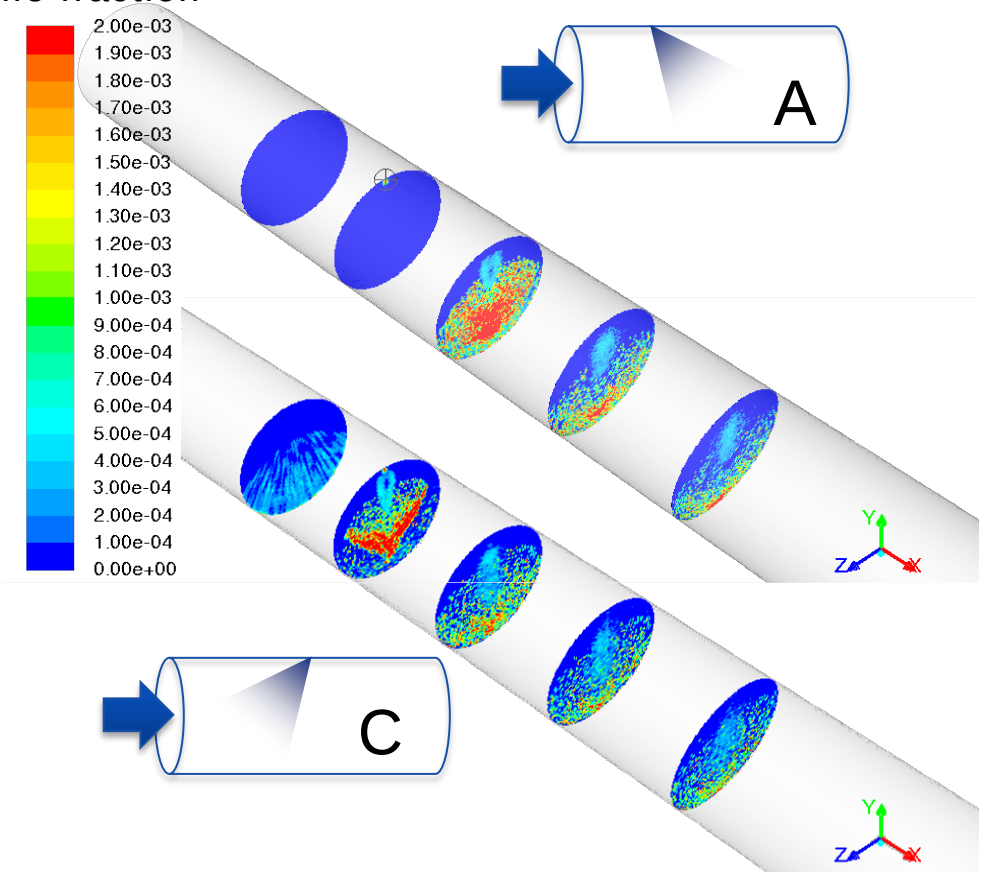
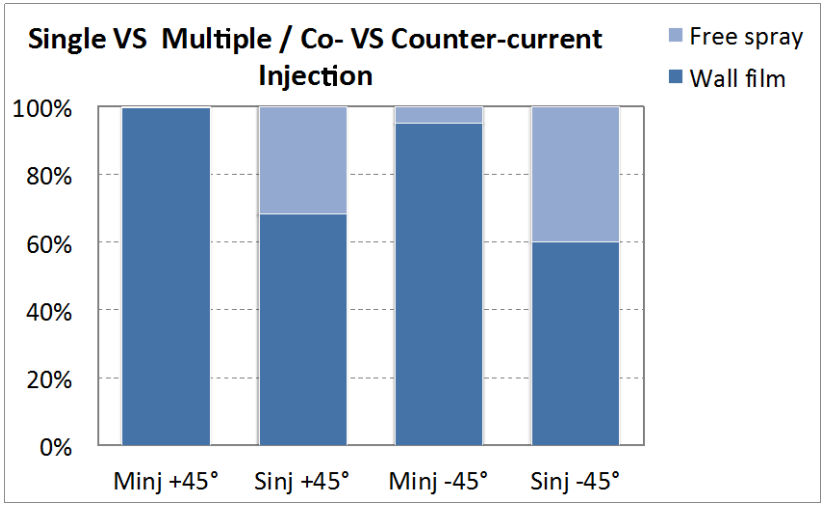
Results: Injection angle

Mean droplet volume fraction



Counter-current injection

- Increases residence time and available mixing distance
- Decreases mass % of wall film



A B C D

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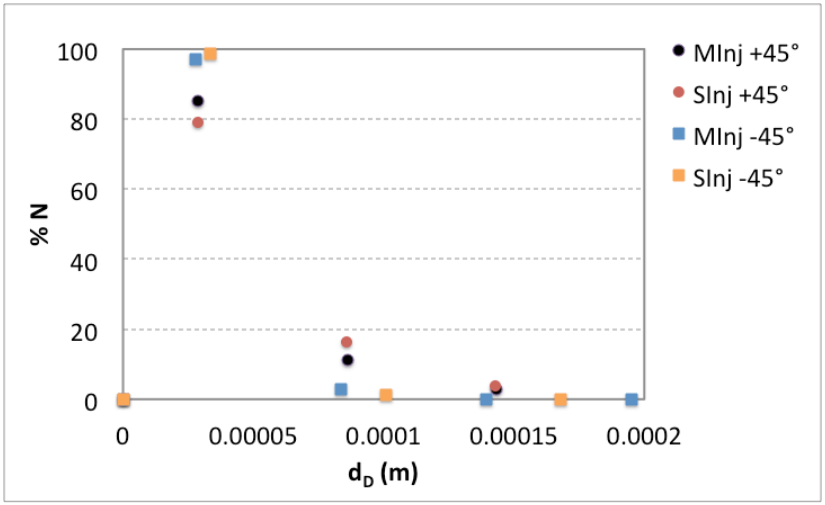
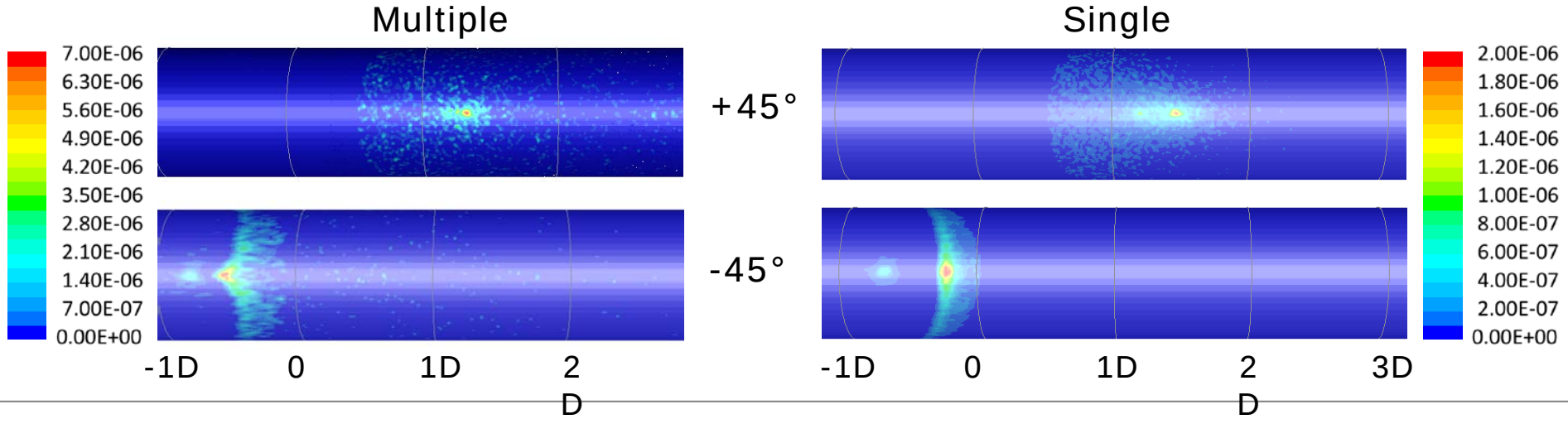
Results

- Droplet size distribution



- Wall film thickness (m)



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Summary

- Effect of urea injection
  - Low injection frequency; each pulse can be studied independently
  - Continuous injection leads to better mixing and thinner wall-film than intermittent injection
  - Counter-current injection leads to better mixing and promotes droplet breakup more than co-current injection
- Effect of exhaust gas pulsation
  - Not significant in droplet distribution at outlet
  - More spread wall film

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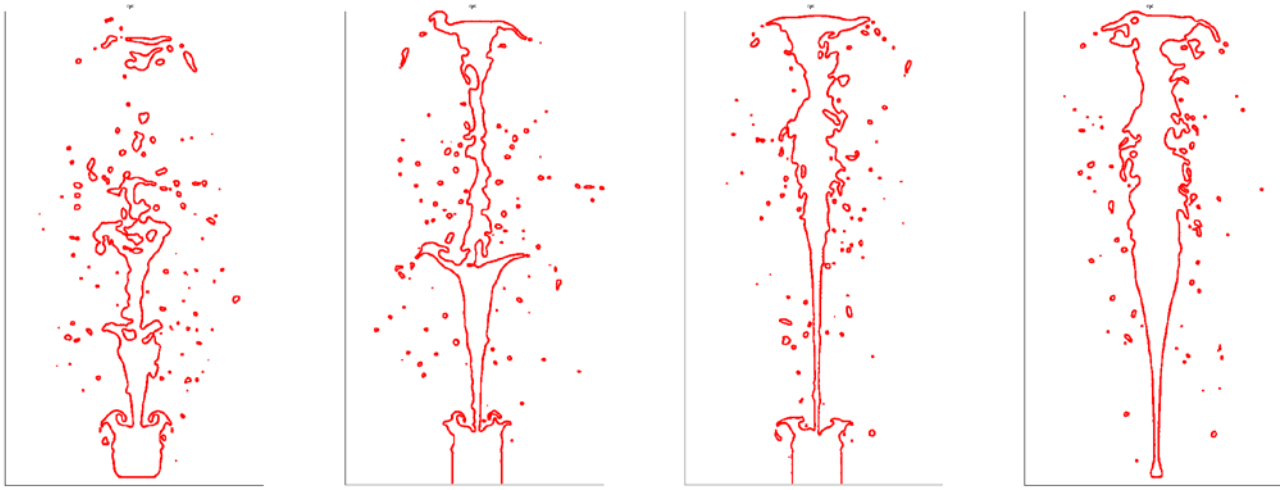
What's next?

- Potential to improve droplet mixing by
  - Using shorter and more frequent pulses
  - Increasing relative velocity between phases: Injection angle, Air-assisted atomization
  - Enhance gas turbulence: Passive vortex generators, Fluidic injection



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What's next?

- Numerical Simulations
  - Run DES and compare mixing mechanisms with RANS
  - Realistic geometric configurations
  - Include chemical reactions
  - Wall-film modelling
  - Assessment of the effect of design proposals