Competence Center for Gas Exchange

CCGEx

”Charging for the future”

Energimyndigheten SCANIA VOLVO BorgWarner

KTH ROYAL INSTITUTE
OF TECHNOLOGY

Control of particle agglomeration with relevance to after-treatment gas processes

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Outline

- Motivation of the project
- Description of the model
- Results
- Future plans

Motivation

NOMAD (https://commons.wikimedia.org/wiki/File:Trafficjamdelhi.jpg), „Trafficjamdelhi“, https://creativecommons.org/licenses/by/2.0/legalcode

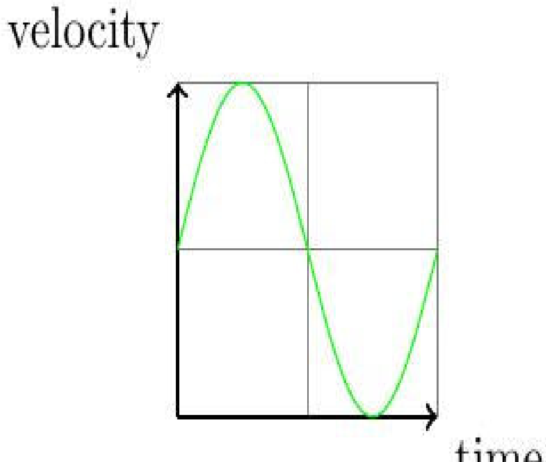
- Nano sized particles in emissions from internal combustion engines(ICE) are a major health issue.
- Larger particles are easier to filtrate.
- Particle agglomeration is one way in which larger particles can be obtained from ICE particulate emissions.

Ruben de Rijcke (https://commons.wikimedia.org/wiki/File:Automobile_exhaust_gas.jpg), „Automobile exhaust gas“, https://creativecommons.org/licenses/by-sa/3.0/legalcode

Scope of the study

- (**Why?**)Reduce the number of particles in the internal combustion engine(ICE) exhaust gases.
- (**How?**)Using flow and acoustic forcing to enhance particle agglomeration.
- (**Insight**)Perform numerical studies to study particle behavior under pulsatile flow conditions.
- (**Goal**)Utilize the developed numerical tools to simulate a real engine exhaust system.

Agglomeration Principle

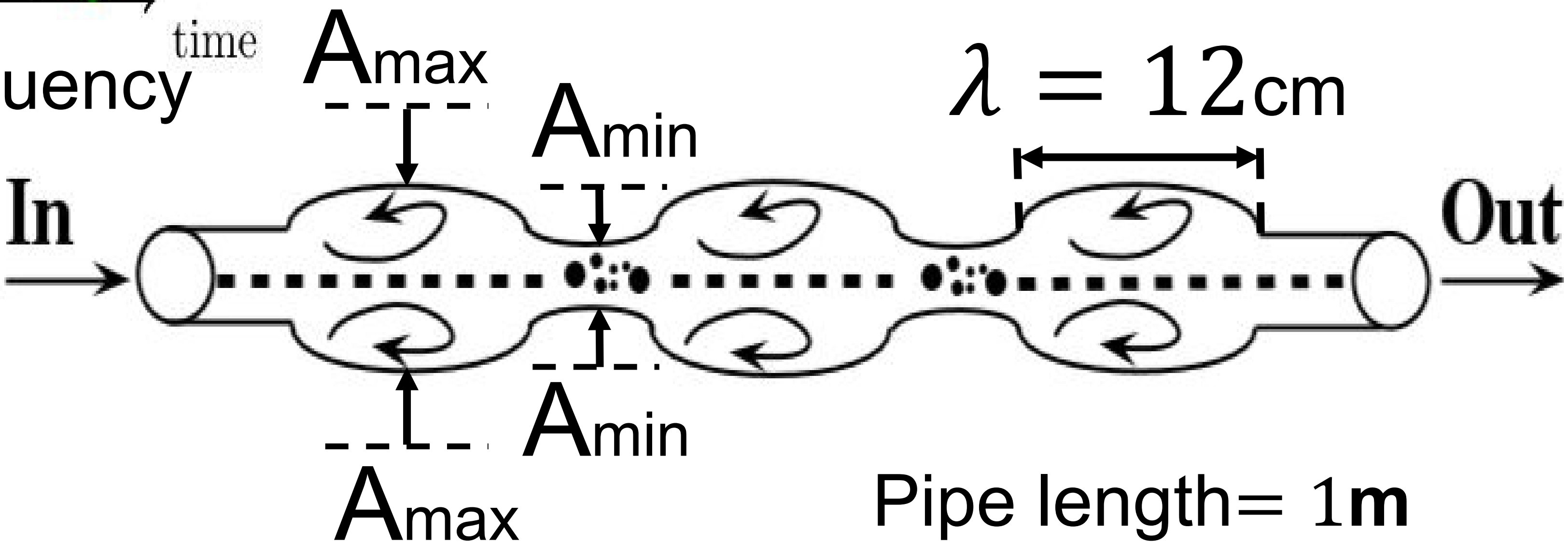


In this **1D** model we have:

- Oscillations with respect to **time**.
- Oscillations with respect to **geometry**.

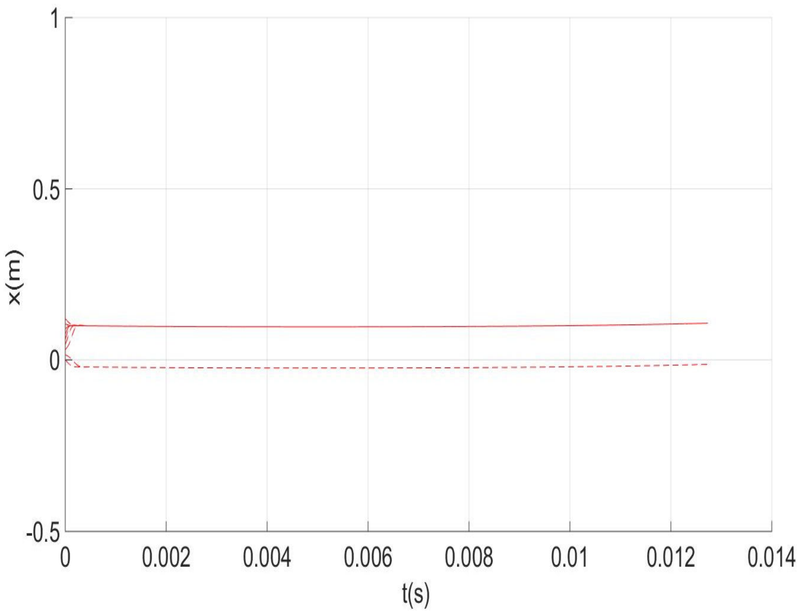
These oscillations will cause particles to accelerate or decelerate based on their location.

f = Frequency

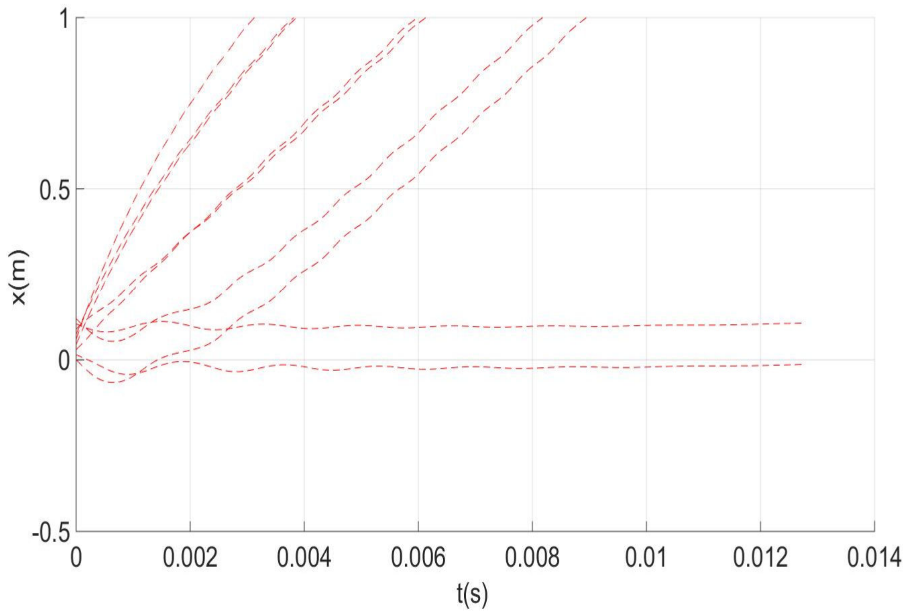


Qualitative picture of grouping vs. non grouping

In the case of grouping all particle trajectories collapse into one of the two bands.



In the case of non grouping particle trajectories move individually and more than two bands can be formed.



Description of model equation

- The model gas velocity equation is given as:

$$v_g(x,t) = \underbrace{V_a}_{\text{Mean Part.}} - V_b\,(\underbrace{\sin(\omega t)}_{\text{Oscillations from engine.}} + C)\,\underbrace{\cos(kx)}_{\text{Oscillations from geometry.}}$$

- The (non-dim)equation for the motion of particles in such a flow field:

$$\ddot{x}^* = \frac{1}{\underbrace{St}_{\text{Stokes number controls inertia}}}\left(v_g^* - \dot{x}^*\right)$$

❑ **Normalization of time, displacement and velocity is done using ω, k and ω/k.**

Important Parameters.

- Two parameters were identified by Katoshevski et.al(2005) as being important.
- The beta parameter given as:

$$\beta = \frac{V_a - \lambda f}{V_b}. \quad \left\{ \begin{array}{l} \text{Mean flow vs.} \\ \text{Oscillations.} \end{array} \right\}$$

- The alpha parameter given as:

$$\alpha = \frac{1}{\sqrt{(V_b^* St)}}. \quad \left\{ \begin{array}{l} \text{Size of the} \\ \text{particles.} \end{array} \right\}$$

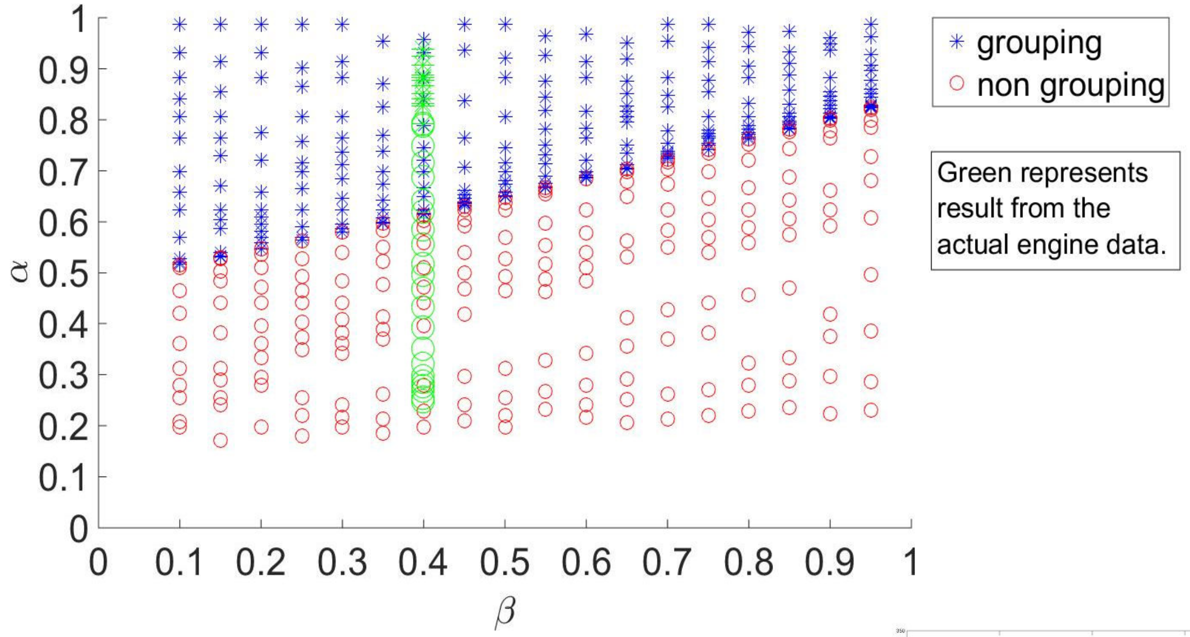
❑ **For grouping to occur $|\beta|$<1 and α should be large.**

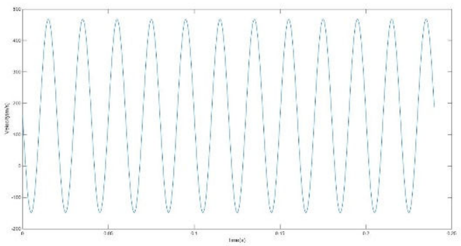
Parameter Studies

- Compare the idealized oscillations in time with the actual engine data.
- Compare different waveforms for the oscillations due to geometry keeping the idealized oscillations in time.

Idealized and actual oscillations from the engine.

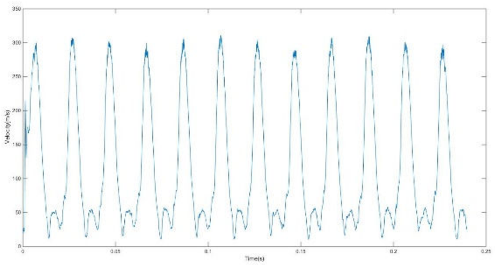
Smaller particle diameter





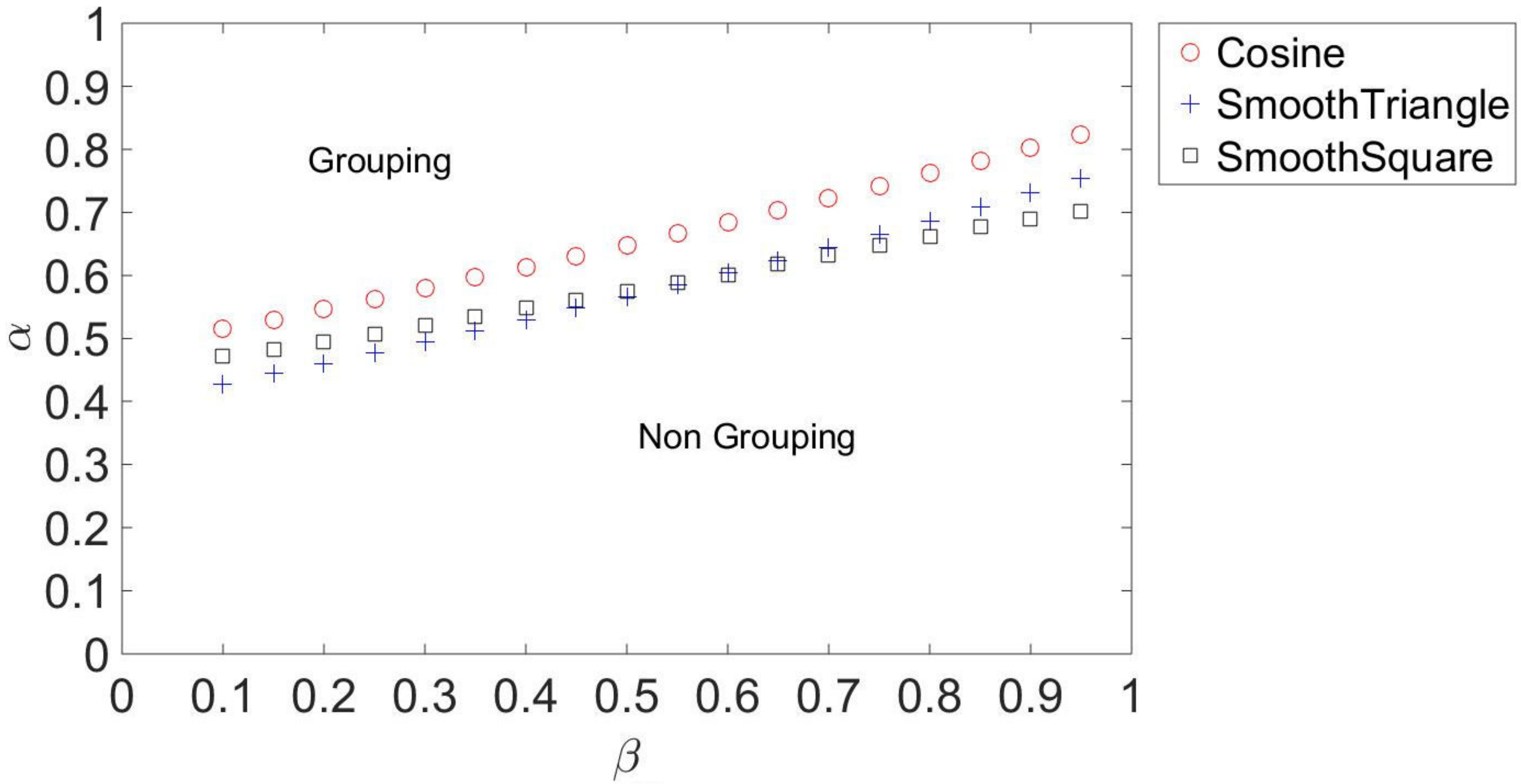
Idealized oscillations

Actual engine data provided by Volvo.



- ❑ **The idealized oscillations under estimate the transition from grouping to non grouping.**

Different waveforms for oscillations due to the geometry



- Different waveforms effect the slope of the transition between grouping and non grouping.

Future plans

- Complete parameter studies with **1D** model.
- Move towards more realistic **3D** geometries.
- Perform high fidelity studies in **3D** using OpenFOAM.

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Design approach

- Let $R = {}^{A_{max}}/_{A_{min}}$, $T = \sin(\omega t) + C$ and $V^* = {}^{\lambda A_{max}}/_{V_d}$, where V_d is the cylinder displacement volume(for one cylinder).
- By applying conservation of mass on the definition of the β parameter one gets:

$$\beta = T\left(1 - 2\,\frac{(V^* - 1)}{(R - 1)}\right).$$

❑ **β parameter can be used to find the optimal area ratio for the pipe.**