VSB2 model for diesel spray simulation and comparison of k-ε with Realizable k-ε turbulence model

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Politecnico di Milano

Overview

- Goal of the project
- Introduction to VSB2 model
- Previous work
- A short introduction to the goals of the current project
- Comparison of turbulence models
- Conclusion and Future work

Goal of the project

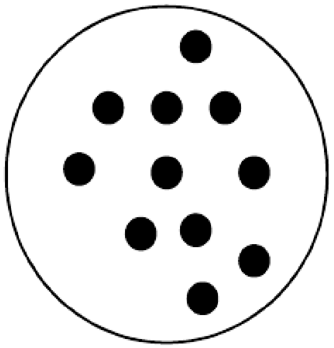
•Implementation of multicomponent / blended fuels in VSB2 spray model
High demand in the automotive industry

•Supercritical effects of evaporation
Recent works have suggested that no sprays exist at elevated pressure and temperatures

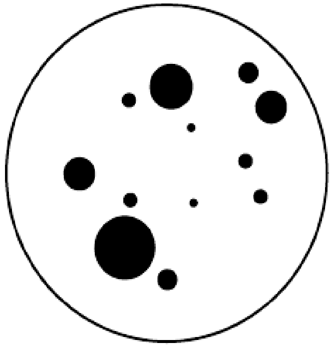
•LES of sprays
For deeper insight into spray formation

Introduction to VSB2 Stochastic Blob and Bubble spray model

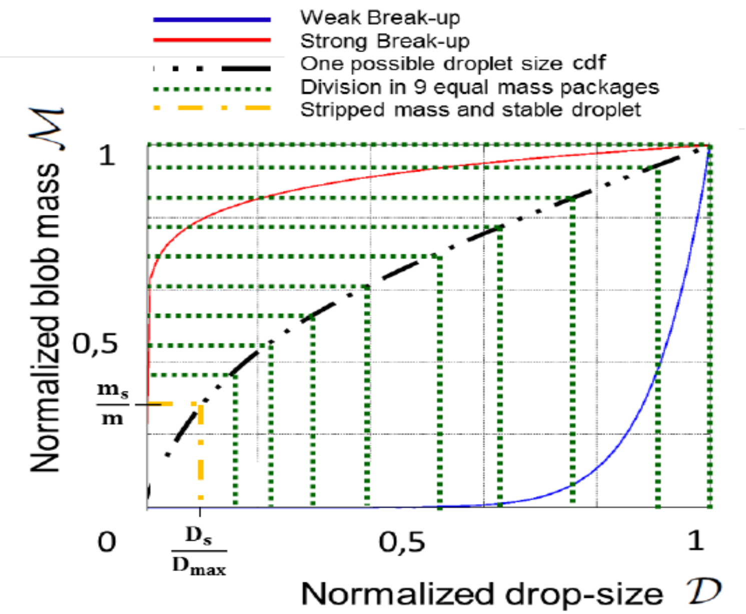
parcel
collection of equal droplets



blob
droplet size distribution
(based on local instantaneous We and Oh), using break-up rate correlations by Pilch&Erdman*

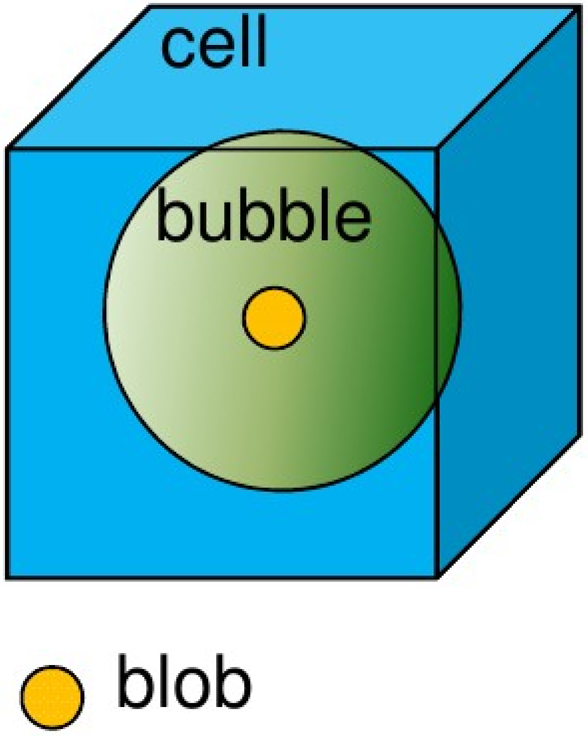


Droplet size distribution



Introduction to VSB2 Stochastic Blob and Bubble spray model

An attempt to reduce grid-size dependency
Maximum possible bubble size is the cell-size



Equilibrium

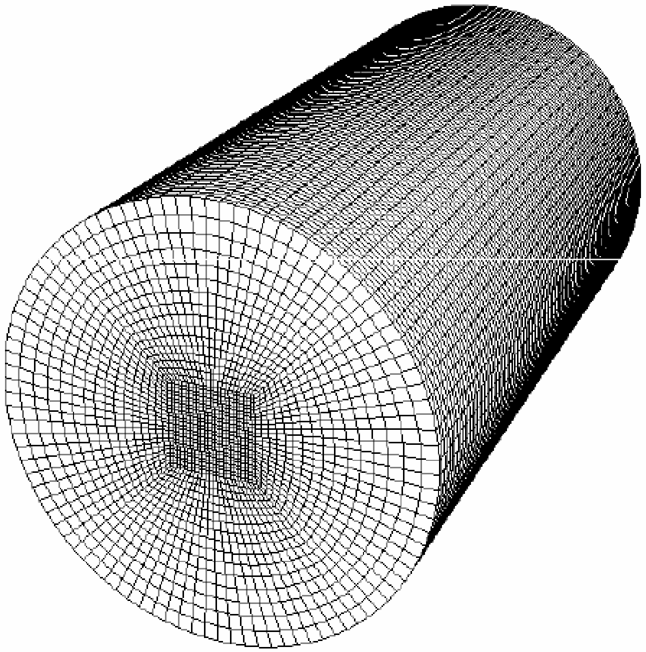
Unconditional robust - Rigorous thermodynamic equilibrium calculation preformed for each blob-bubble pair

$$V_{bub} = N_D \frac{\pi}{6}\left[(D_B + l_t)^3 - D_B^3\right]$$

$$l_t = min\left[C\frac{k^{3/2}}{\varepsilon}, V_{cell}^{1/3}\right]$$

Mesh Geometry: Same volume as Spray chamber at ECN, Sandia

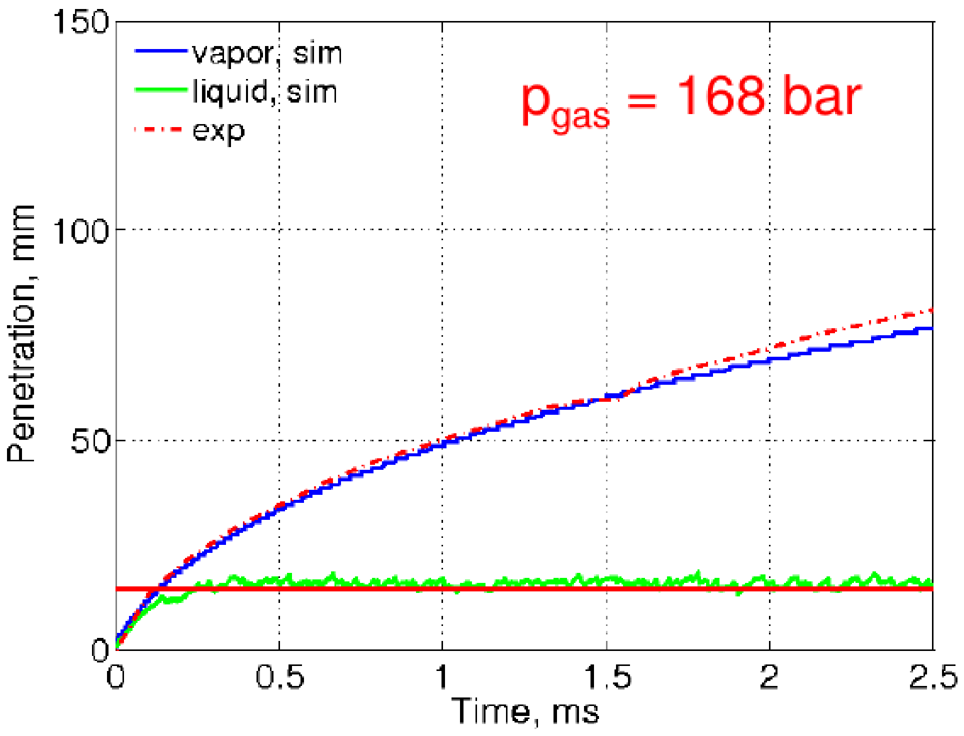
Injection in the center,
directed downward along the axis



3D view

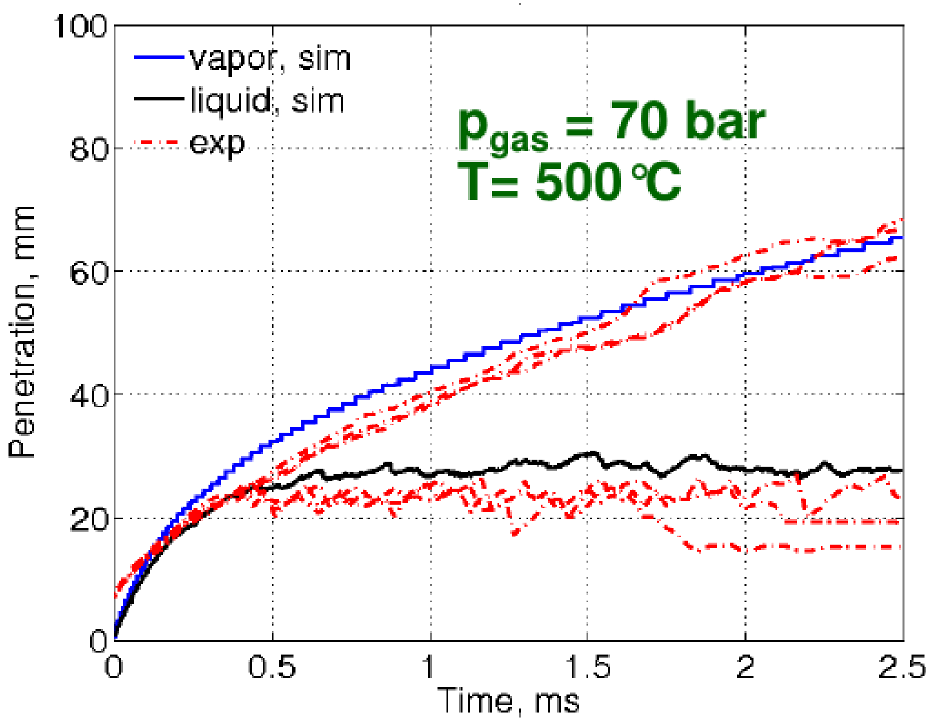
Previous work – Anne Kösters, Anders Karlsson

Fuel: n-hexadecane
P_{inj}: 1370bar, Tgas: 727deg celsius



Experiment Siebers and Naber

Fuel: n-hexadecane
P_{inj}: 1200bar, Tgas: 500deg celcius



Experiment Chalmers HP/HT Rig

- Validation of the VSB2 spray model against spray A and spray H, A.kösters & A.Karlsson, Atomization and Sprays
- Previous implementation in OpenFoam 1.6.x
- Migration from 1.6.x to 3.0.x

Multicomponent fuel modeling

Continuing the work by visiting master student Francesca Pogliani from Politecnico di Milano

In case of a single component this is straight forward to coupling evaporation and heating/cooling of the surrounding gas and can be easily be implemented by an iterative procedure.

In case of multicomponent evaporation, substantial complexity increase due to the fact that each component has its own thermodynamical equilibrium, whereas the bubble temperature will depend on evaporation of all components.

The goal is to implement a direct numerical method for the coupling of evaporation and heating/cooling of multicomponent mixtures.

Super critical conditions of evaporation

- Research questions whether spray really exists at high pressure/high temperature conditions of modern diesel engines

- Alternative is a dense supercritical jet without droplet formation.

- This project investigates for possible supercritical phase transition in diesel sprays.

LES of sprays

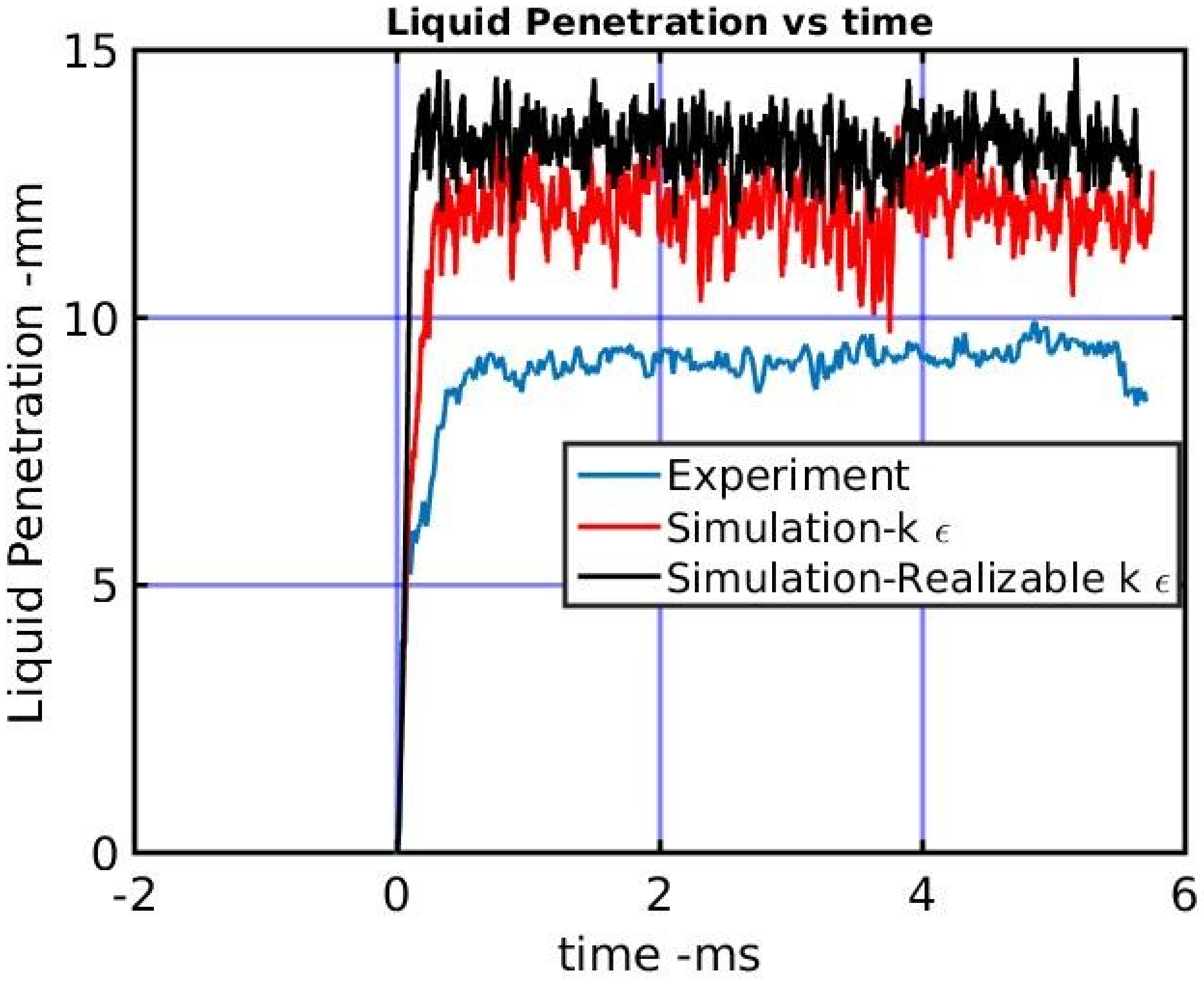
- To obtain correct air entrainment in a fuel spray near the nozzle and accurate flame lift-off lengths
- LES is computationally expensive
- The approach of this project is to use LES to simulate the unsteady behavior of sprays and flame fronts.
- Use the results of LES to modify the standard k-epsilon models for industrial applications.

Comparison of k-Ɛ with Realizable k-Ɛ turbulence models for standard spray model

- Outcome of Realizable k-Ɛ is that it can be used for circular jets.

- Difference from standard k-Ɛ is that the there is a new formulation for turbulent viscosity and a new equation for epsilon.

Comparison of Liquid penetration : k -Ɛ and Realisable k -Ɛ



Case	Spray H
Geometry	Cylindrical Mesh

Summary

- Introduction to VSB2
- Previous work
- Comparison of turbulence models

Future work

- Implementation of VSB2 in OpenFoam 3.0.x
- Further development of VSB2: Implementation of multicomponent fuel

Research gap

- Standard spray models in openFoam and other commercial softwares require a lot of tuning and in most cases grid size dependent.

- The approach followed in this project ensures the above by employing rigorous thermodynamic calculation for the interaction between the gas and liquid phase.

- This ensures a robust model with minimal tuning parameters and grid size independence.

- Modify standard two equation k-epsilon turbulence models for industrial applications by using the results from LES simulations to capture fine details from unsteady spray simulations