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Modelling and Analysis of the Effect of Process and Geometry Parameters on Multiphase Flow Formation in ACLR Atomizers

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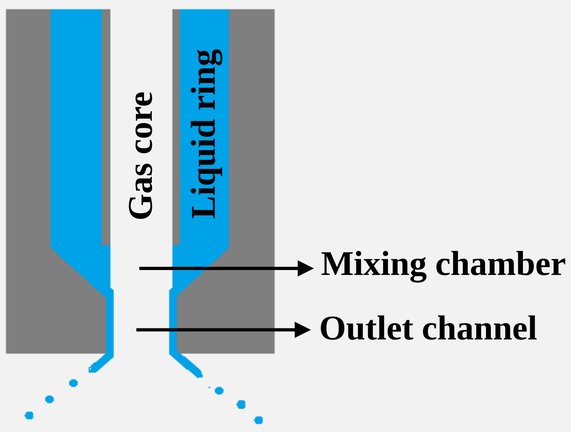
Motivation

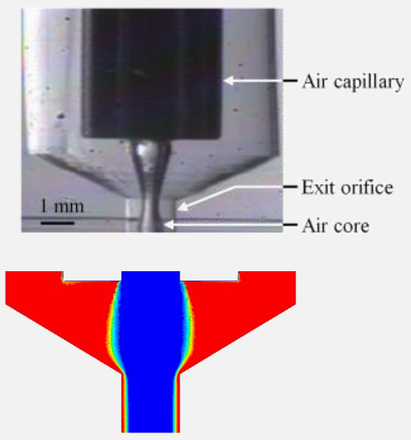
Spray drying:

Widely used process for the production of powders from liquid feeds

Air-Core-Liquid-Ring (ACLR) atomizers:

Suitable for atomization of highly viscous feeds





Process function of ACLR atomizer?

Relation between operating conditions, geometry parameters, internal flow and spraying performance

Background

A vertical annular flow, with a thin liquid lamella, is formed inside the system. The lamella breaks into droplets after exiting the nozzle

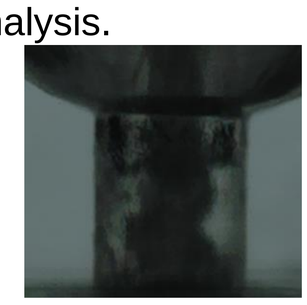
↓ **Energy consumption:** Low air flow and pressures (0.3-1 MPa) mean less energy input.

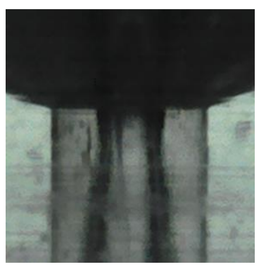
↑ **Viscous feeds:**
High solid contents makes drying more efficient.

Materials & Methods

Atomization rig (0.3 - 1 MPa):

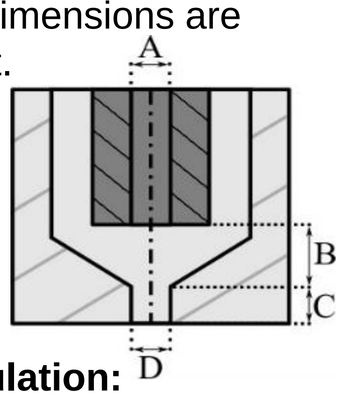
- Inline measurement of liquid lamella thickness with high speed video camera (Integrated Design Tools Inc., 10-20 kHz), and image grey scale gradient analysis.





ACLR Nozzle:

- In-house designed geometries, printed in steel and PMMA. Dimensions are parameters of interest.



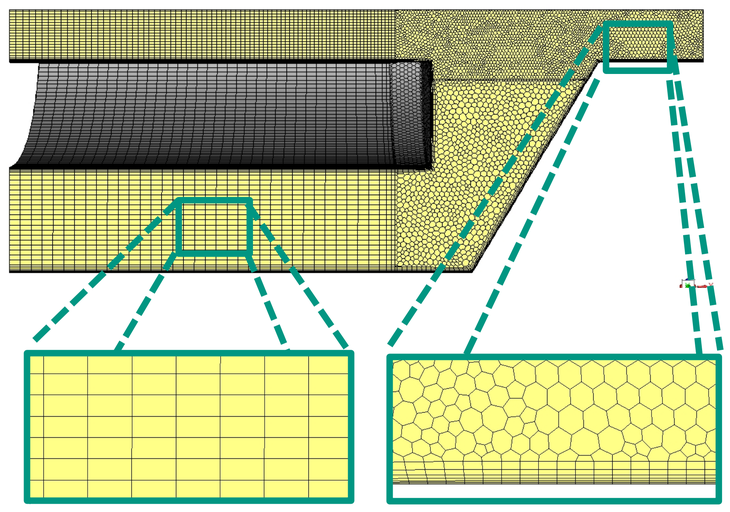
A: Gas core diameter
B: Mixing length
C: Outlet length
D: Outlet diameter

Physic models of simulation:

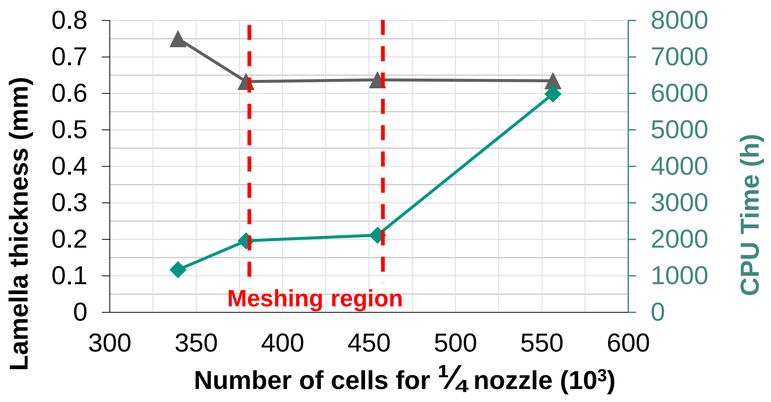
- Volume Of Fluid (VOF) model to represent multiphase flow, with compressible gas phase and incompressible non-Newtonian liquid.
- Fixed liquid mass flow. Fixed inlet gas pressure. Quarter of nozzle for mesh analysis.

Results I

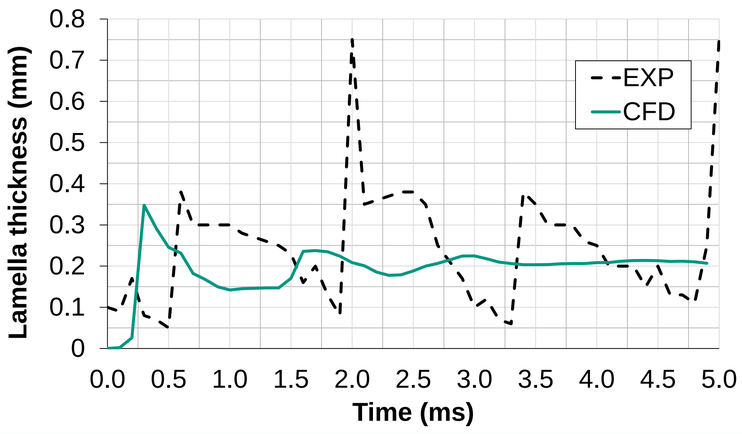
Mesh independence tests performed, to ensure that it would not affect results. Regions of interest meshed with polyhedra; while inlets are meshed with prisms.



↑ **number of cells** → average **lamella thickness** stabilizes, but ↑ **CPU time.** Mesh density should be in plateau region

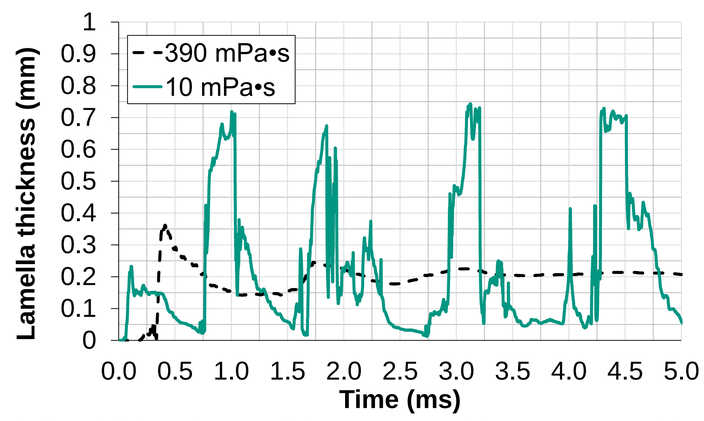


- **Turbulence model:** The k-ω SST model is the best RANS option. LES must still be checked.
- **Experimental validation:** Flow stabilizes in simulations but not in experiments.



Results II

- Similar average lamella thickness between experiments (0.25 mm) and simulations (0.2 mm) ≈ 16% Error
- Small difference between experimental (2.7%) and computational (3.6%) air-to-liquid ratios.
- Using fixed mass flows caused over prediction of required pressure of up to 150%.



→Stabilization of flow could be caused by incorrect prediction of viscosity in the simulations. Low viscosity flows have the expected instability.

Conclusions & Future Work

- The proposed mesh can represent the system without affecting the simulation.
- LES has yet to be evaluated for calculation of vortices and turbulence.
- The stabilization observed in high viscosity feeds in the simulation needs to be studied, to see if it comes from numerical artifacts or predicts how a perfectly controlled system should operate.
- More experiments with different viscosities should be performed, to better validate the CFD model.
- The effect of nozzle geometry must be studied.

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