Dynamics of Non-Spherical Compound Metal Particle in Non-Uniform Flow Field

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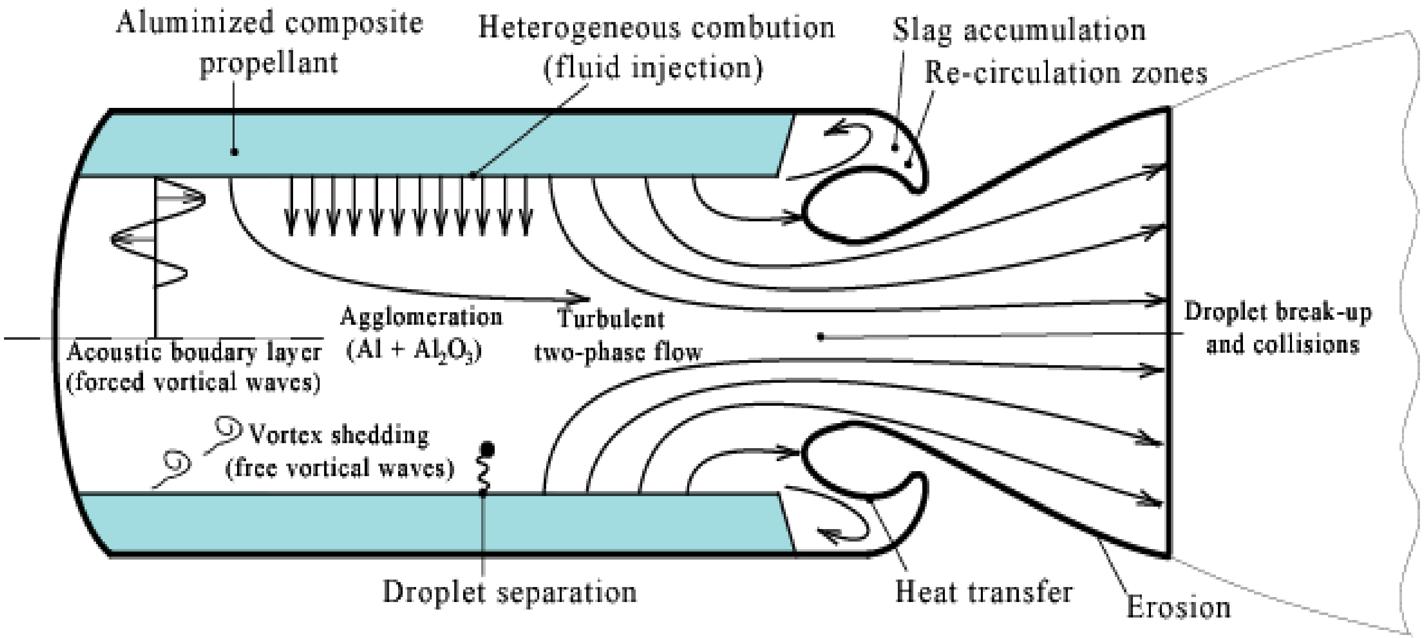
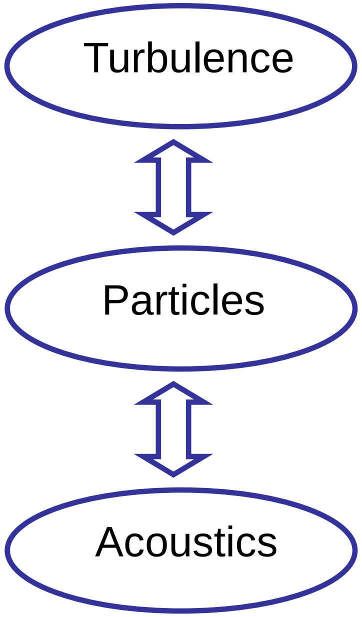
Introduction





Role of particles

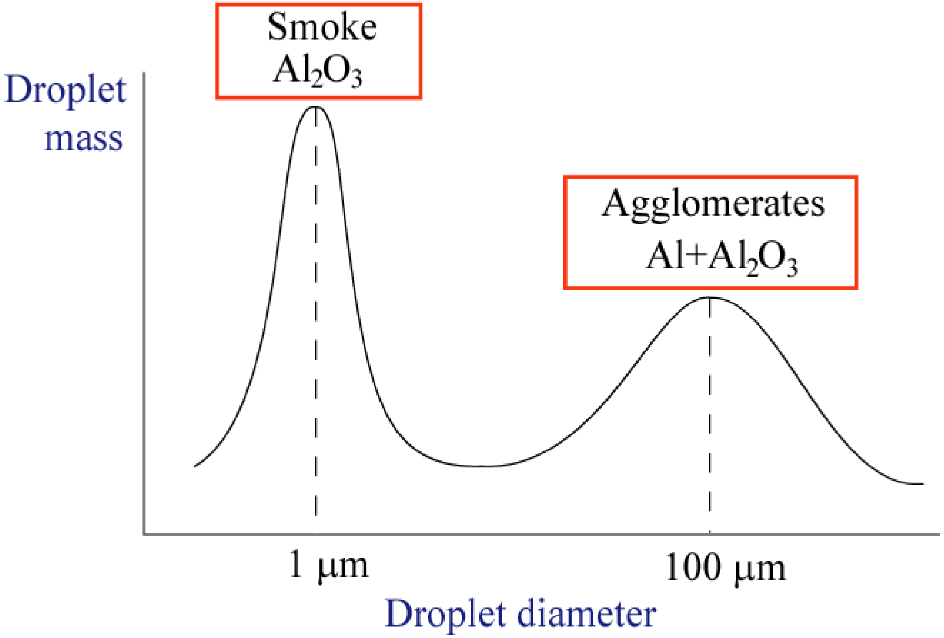
Positive

- Increasing heat release/performance
- Modulation of turbulence
- Damping acoustics instability

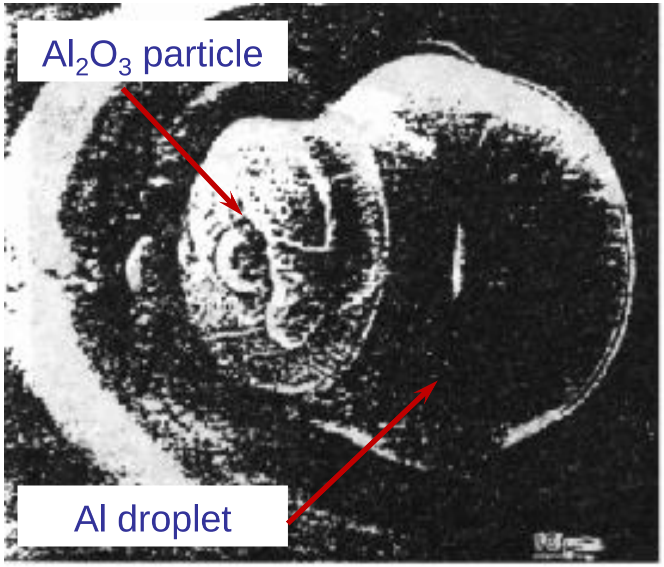
Negative

- Agglomeration
- Slag formation/accumulation
- Driving acoustics instability

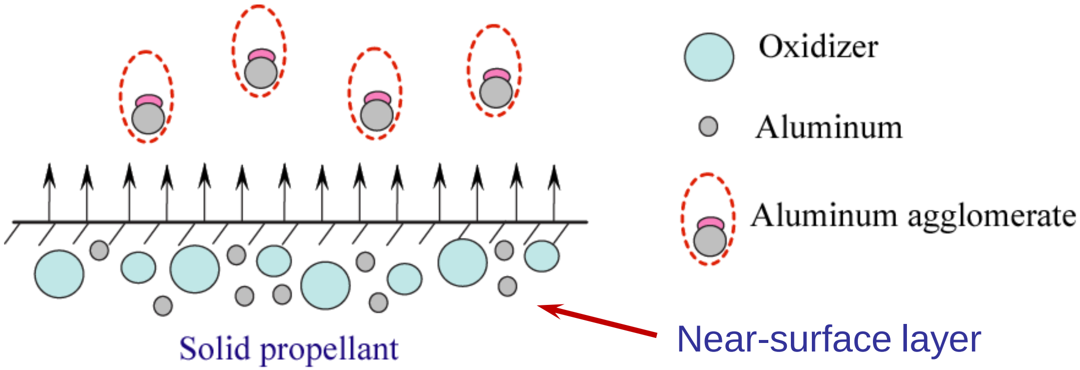
Agglomeration



- Bi-modal distribution
- Agglomerates ($Al + Al_2O_3$)
- Smoke (Al_2O_3)

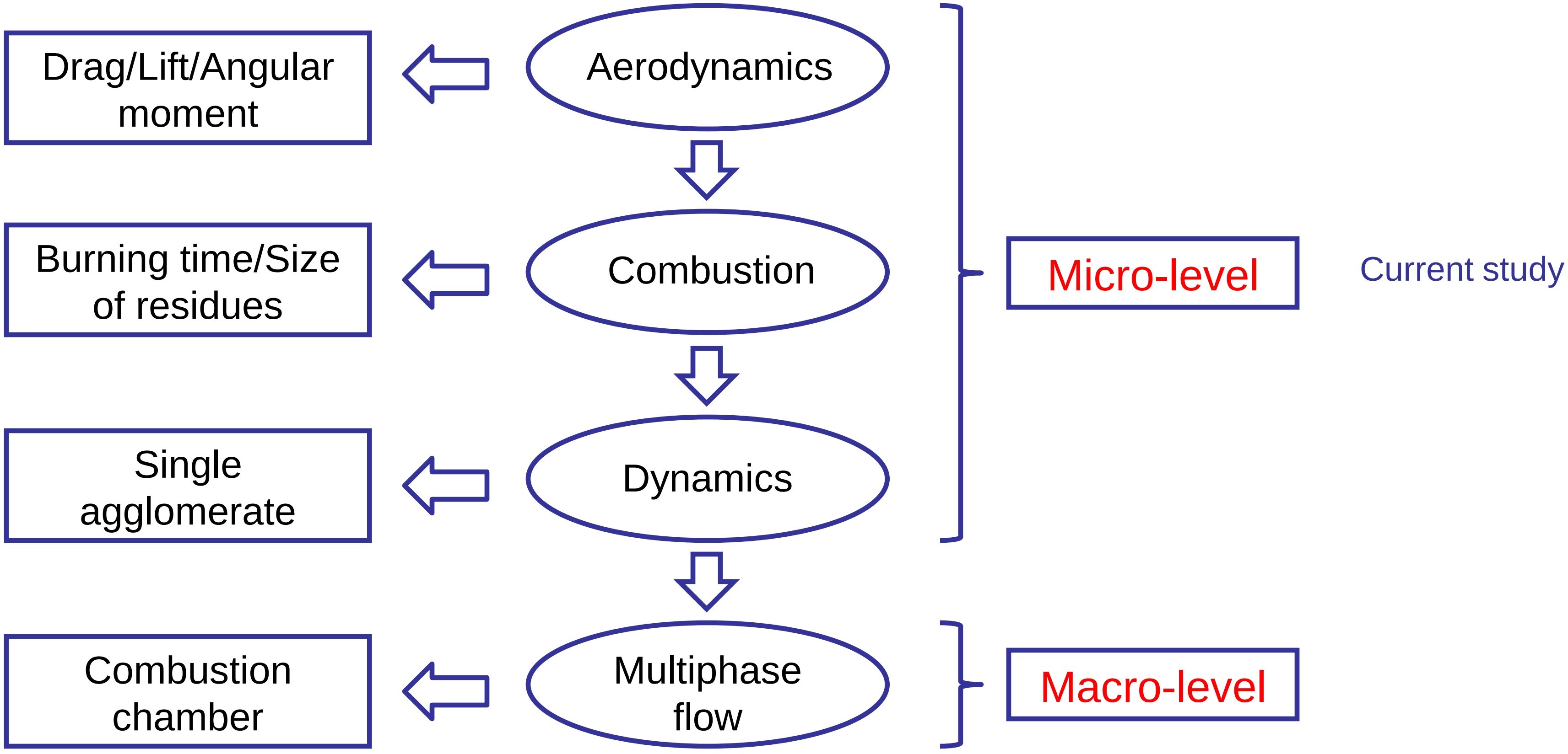


Aluminium droplet with oxide cap
(L.E. Olsen, M.W. Beckstead, 1996)

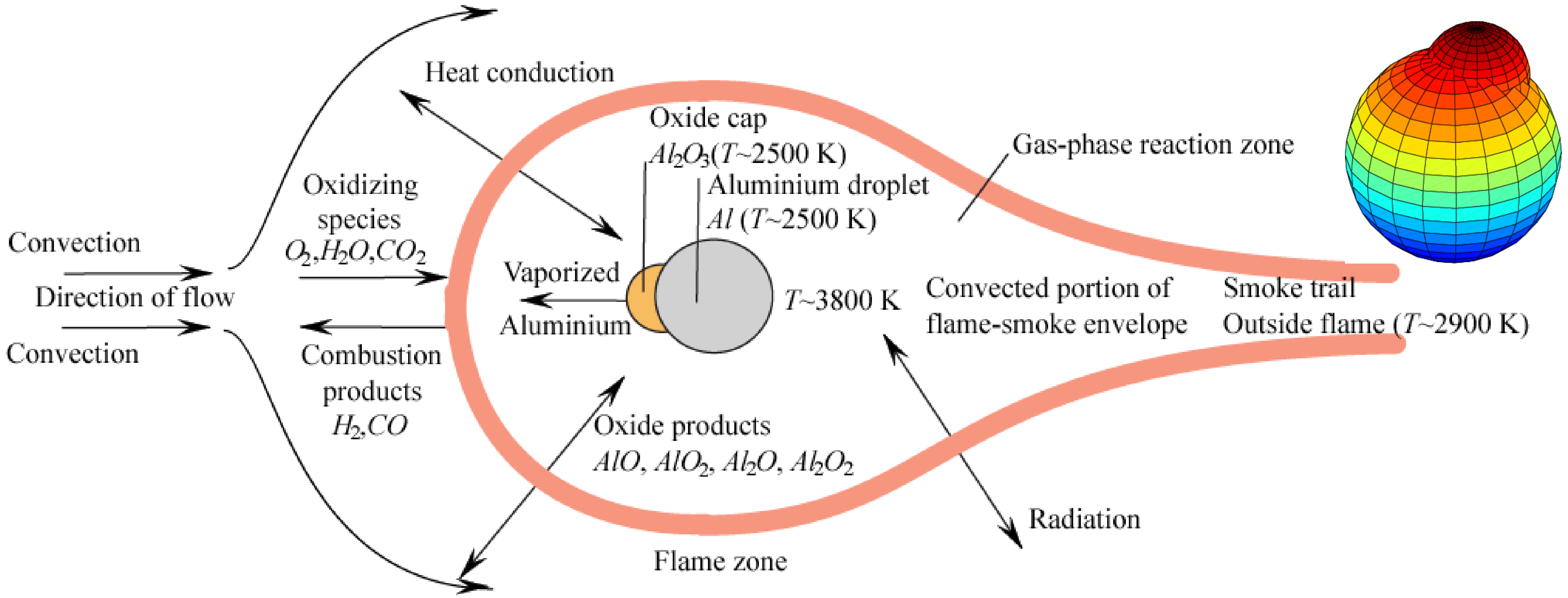


Aim and Objectives

The study aims to develop numerical analysis of the dynamics and combustion of aluminium droplet with oxide cap to improve the current understanding and modelling capabilities of the complex internal flows in the combustion chambers of SRMs.



Modelling and Simulation



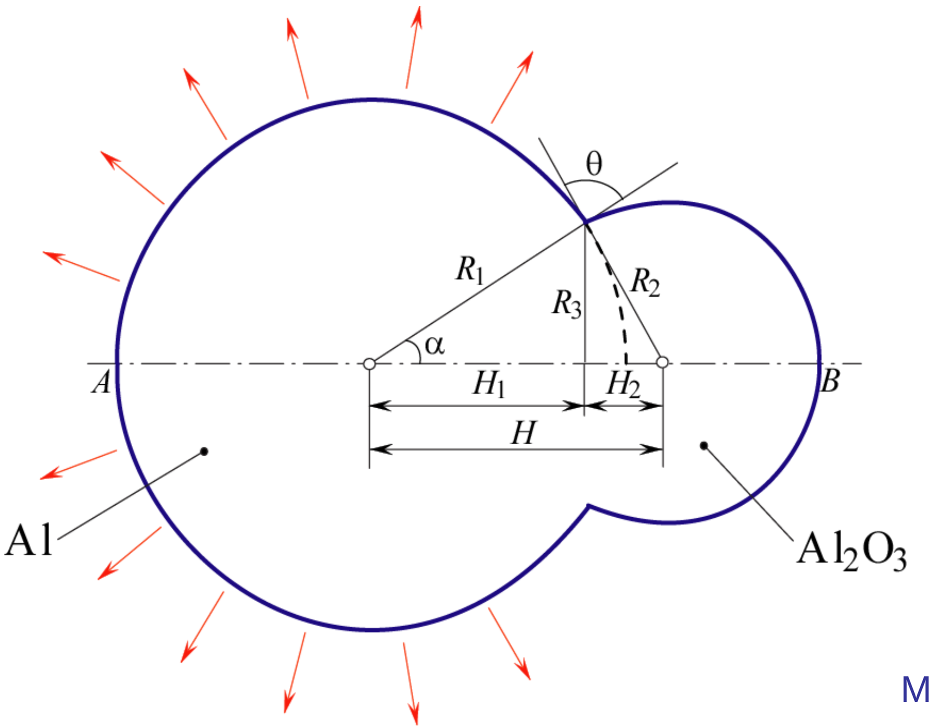
Mathematical model

- Forced convection
- Growth of oxide cap
- Variable transport properties
- Reaction mechanism

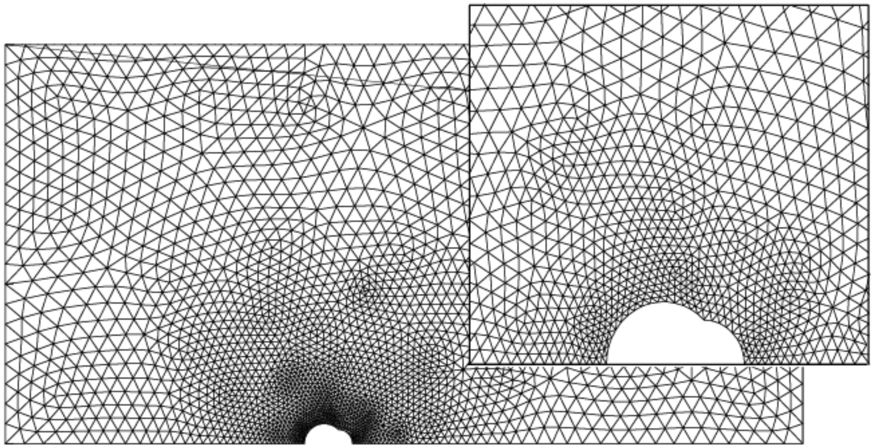
Computational procedure

- Unstructured mesh
- High resolution schemes
- Multigrid method
- Preconditioning

Geometry and Mesh



Shape of droplet with oxide cap



Tetrahedral mesh

Modelling

- Two spheres
- Contact angle
- Droplet surface
- Cap surface

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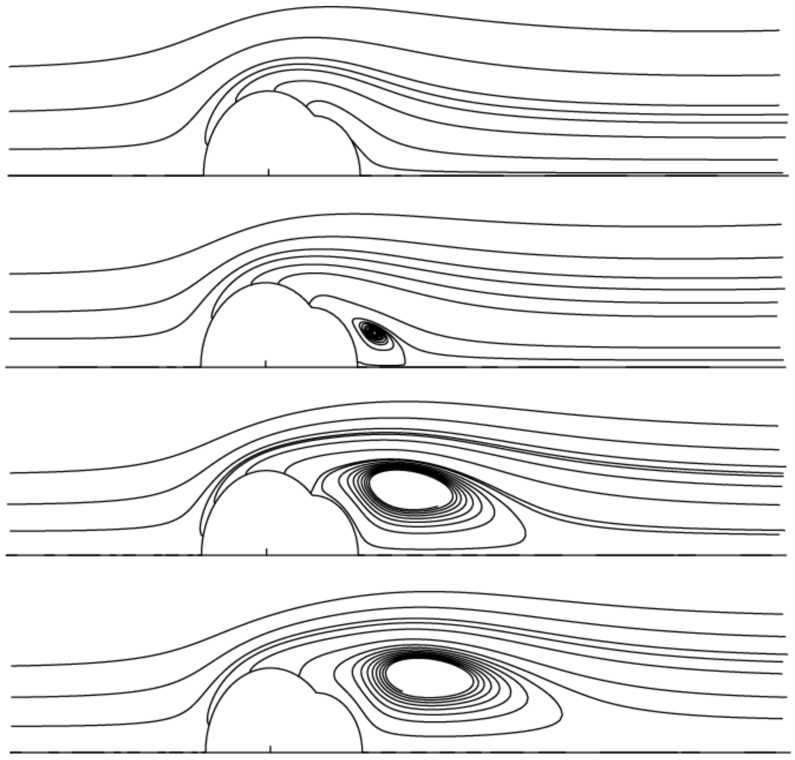
Iterative procedure

- Six parameters
- Yang's equation
- Fluid injection
- Solid surface

Flow Regimes



Re = 10

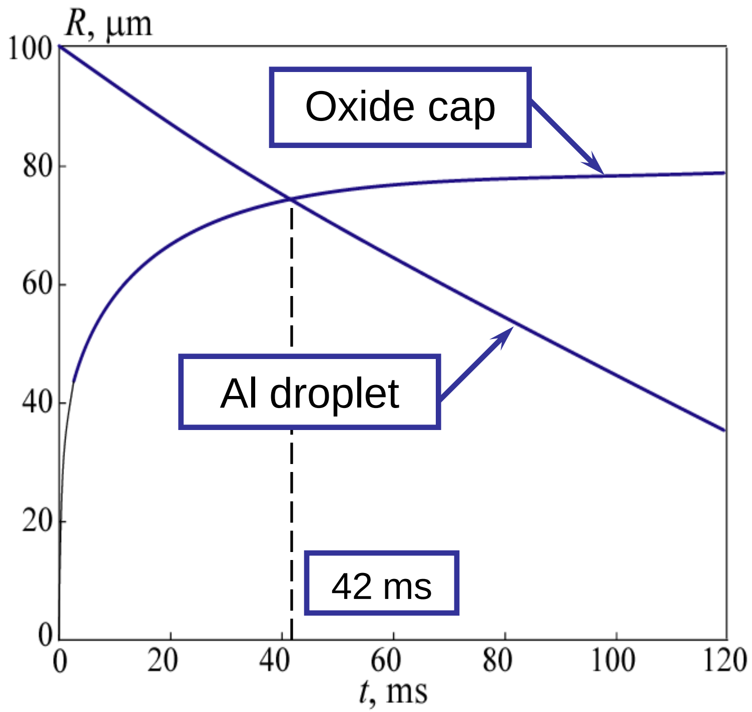
Re = 40

Re = 80

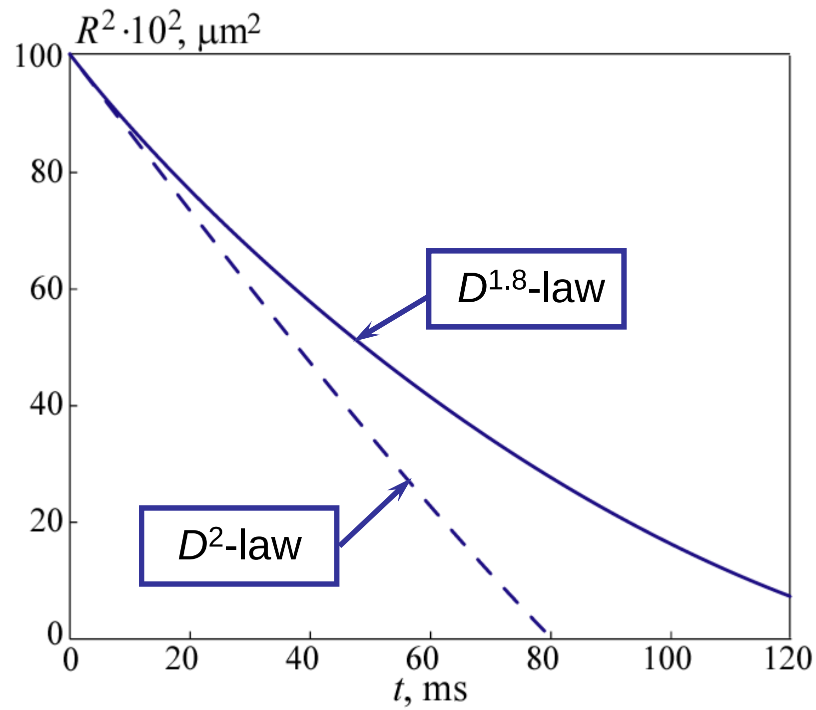
Re = 100

	Sphere	Agglomerate	Regimes
1	Re < 210	Re < 250	Stationary
2	Re ~ 210 ÷ 380	Re ~ 250 ÷ 410	Periodical
3	Re > 380	Re > 410	Non-stationary

Droplet Radius



Radius of droplet and radius of oxide cap



Droplet radius squired

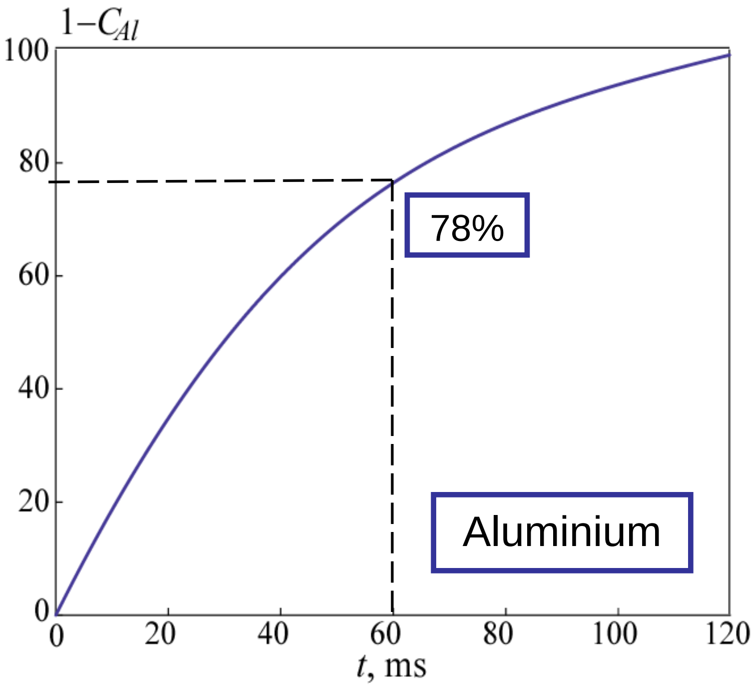
d_0 = 100 µm

T_b = 2750 K (boiling point)

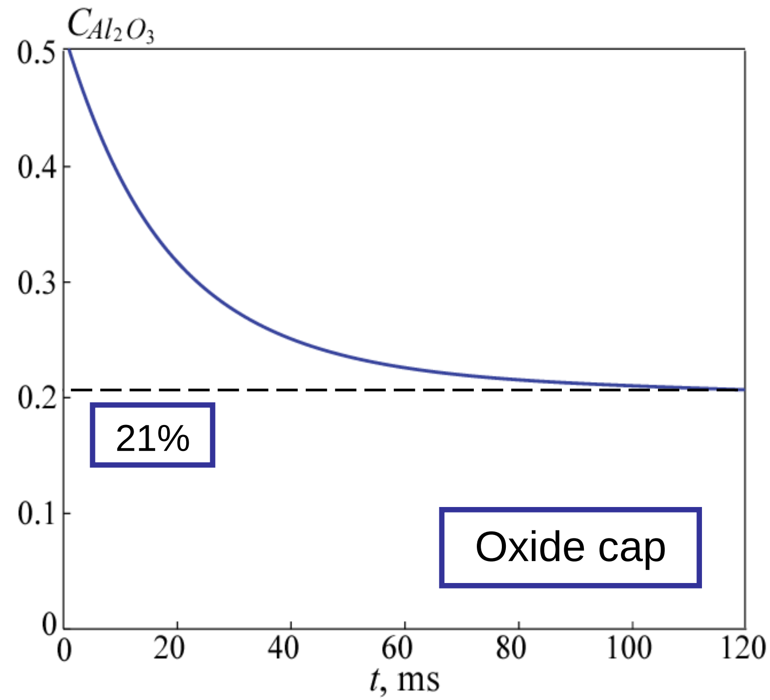
p = 10^5 Pa

- Deviation from D^2-model
- Exponential factor of 1.8
- Large scatter of the results

Metal and Oxide Fractions

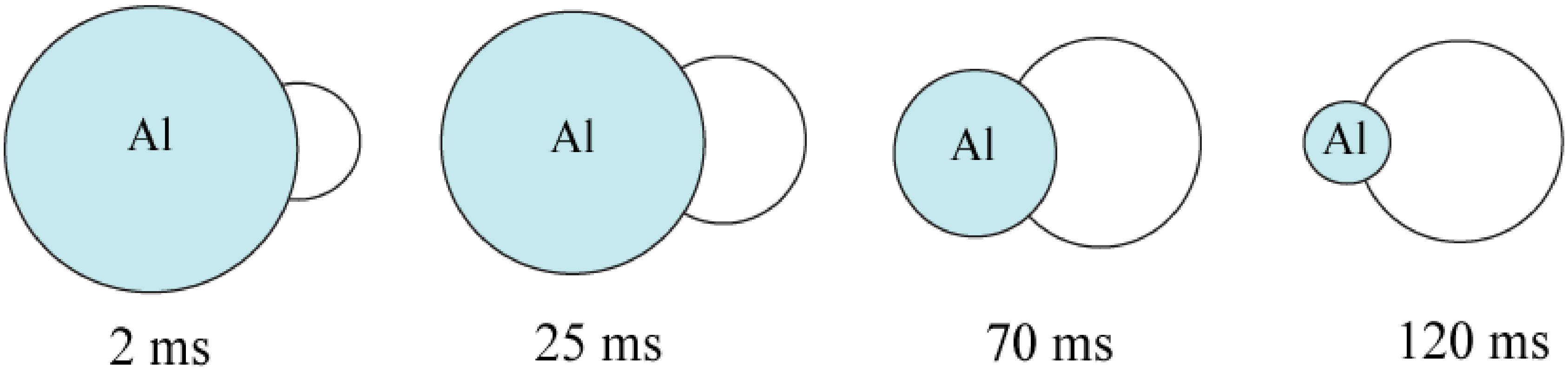


Time history of percentage aluminium burned

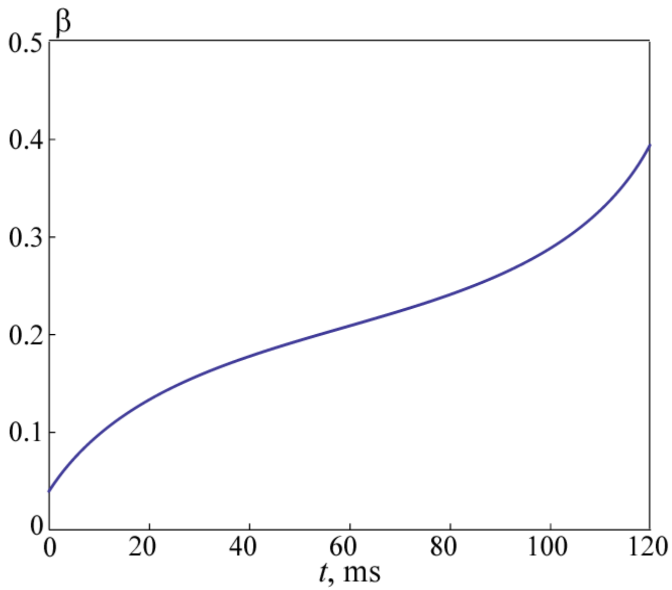


Time history of percentage oxide cap

Droplet Evolution

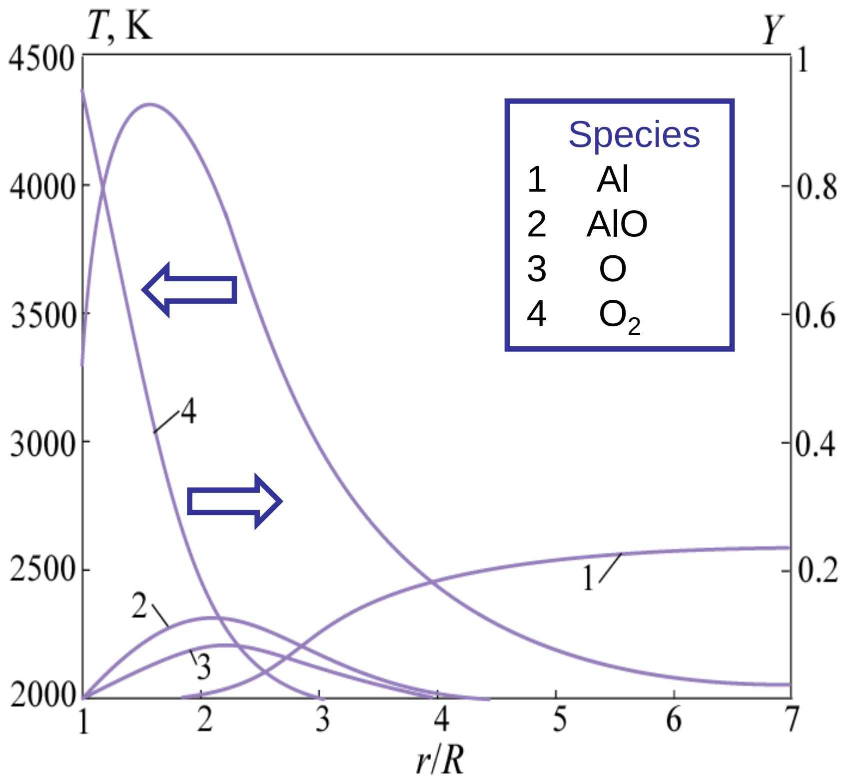


Evolution of aluminium droplet with oxide cap in time



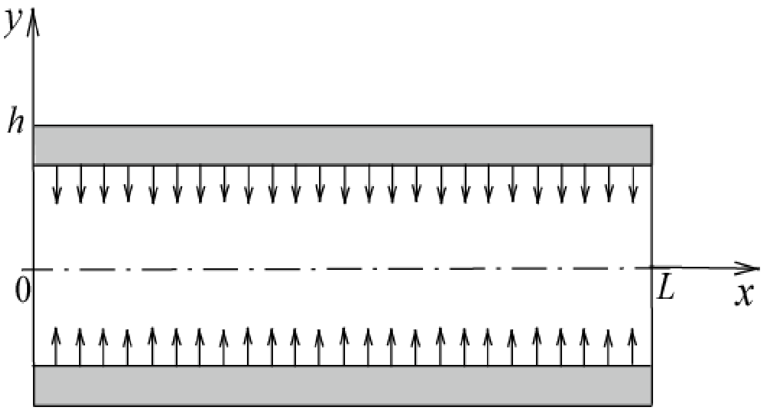
Time history of fraction of aluminium surface area blocked by oxide cap

Temperature and Species



Temperature and species

Flow in Channel



Flow with fluid injection

Radius/Length

h = 0.02 м

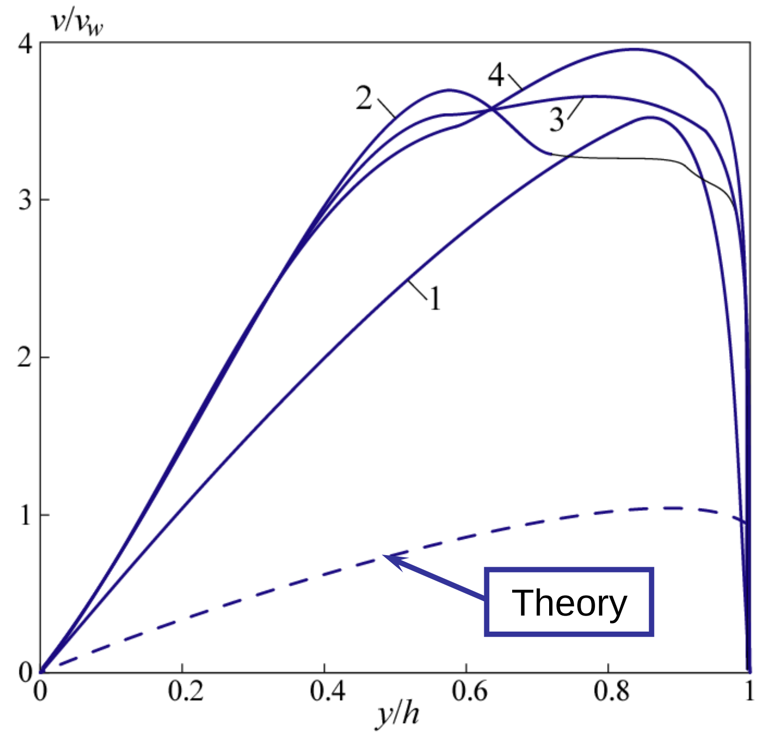
L = 0.6 м

Injection velocity

v_w = 0.25 m/s

Mesh

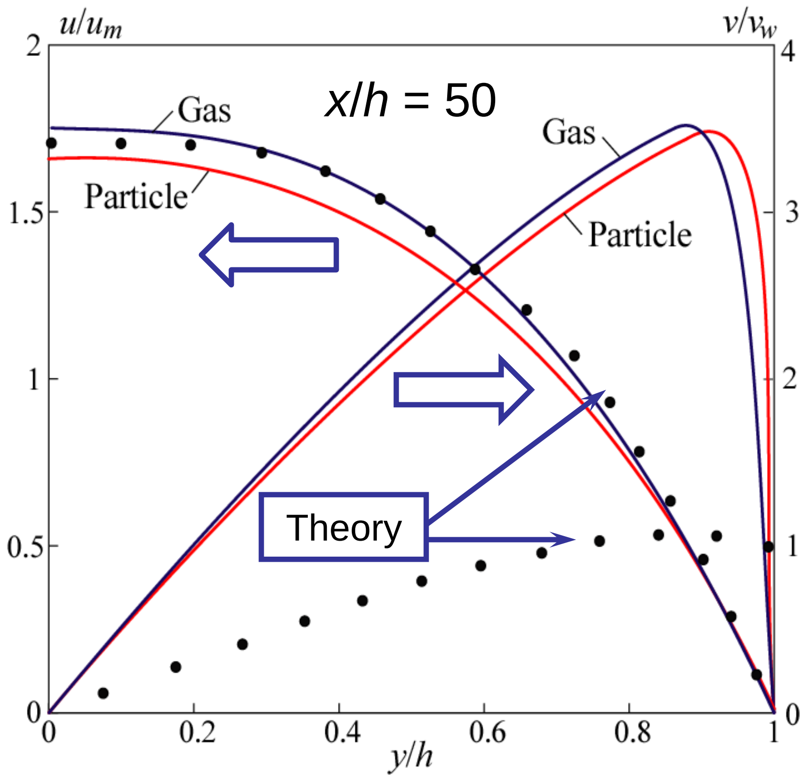
400×100



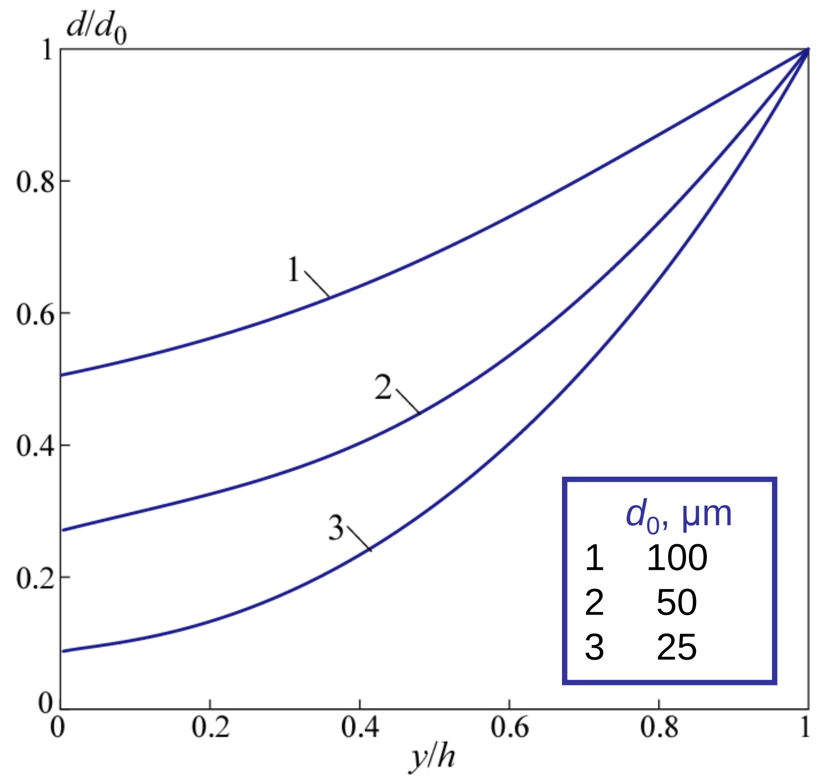
Radial velocity

	x/h	
1	30	RANS
2	10	LES
3	20	LES
4	30	LES

Particle Diameter

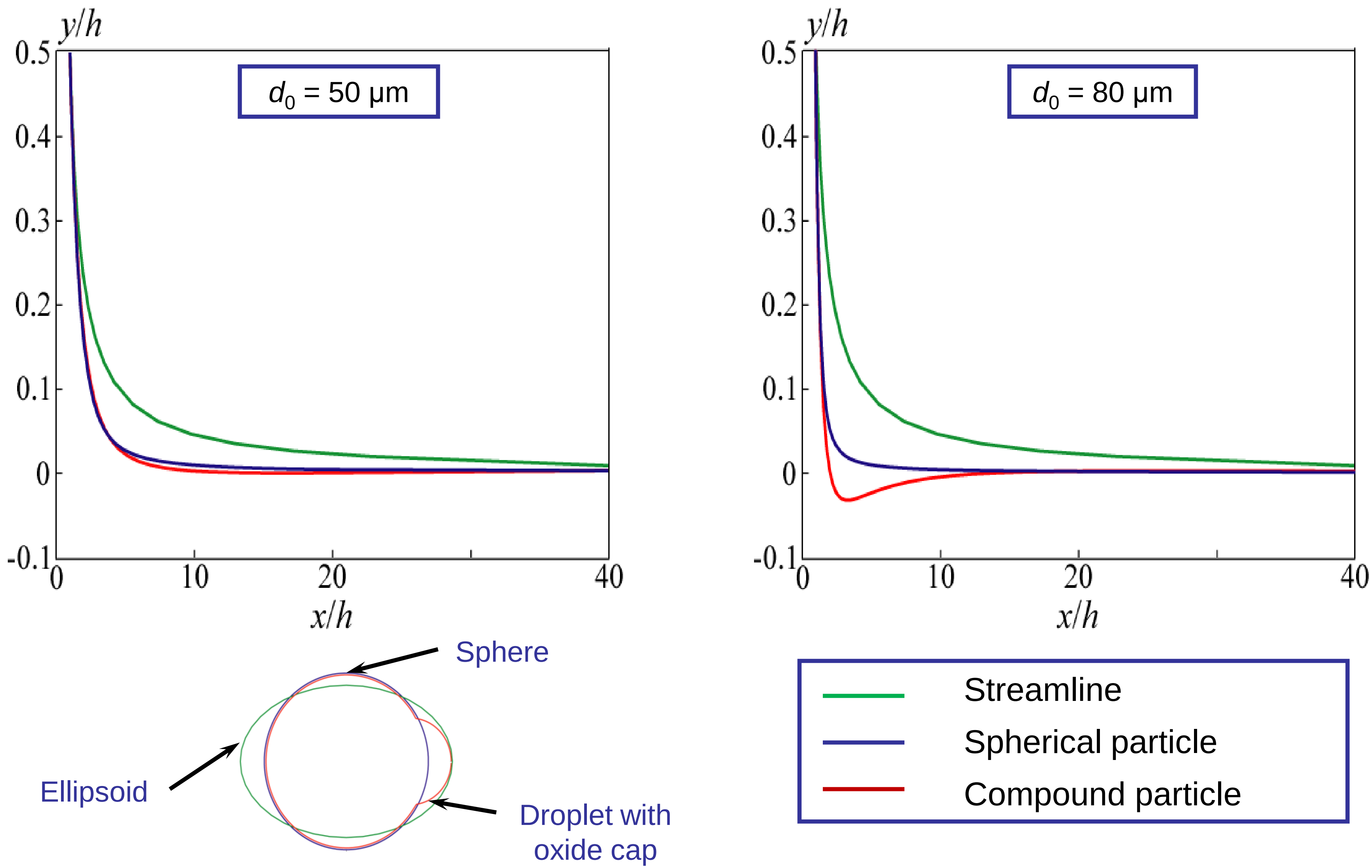


Axial and radial velocities
(d_0 =20 μm)



Particle diameter

Particle Trajectories



Conclusions

The flowfield over aluminium droplet with oxide cap has been computed. Effects of the convective stream show that a symmetry hypothesis usually used in many models is not suitable.

Further work is needed to understand various phenomena not clearly identified including the part of oxide formed on the propellant surface, the droplet size under which a transition from diffusion-limited to kinetically-controlled burning occurs, the effects of turbulence and acoustic-related instabilities on droplet combustion.

THANK YOU FOR YOUR ATTENTION!