Effect of Added Mass on the Dispersion of Small Bubbles

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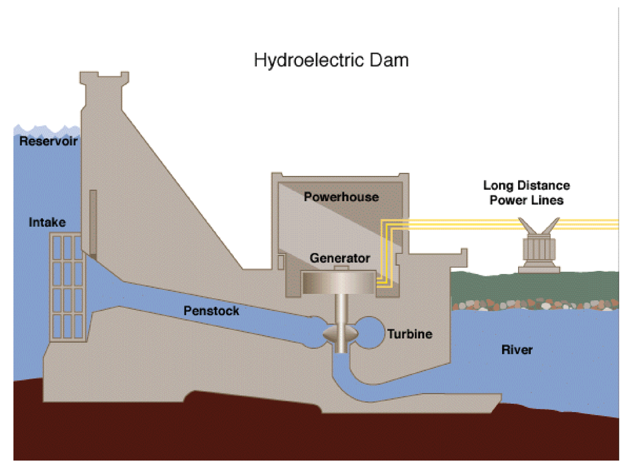
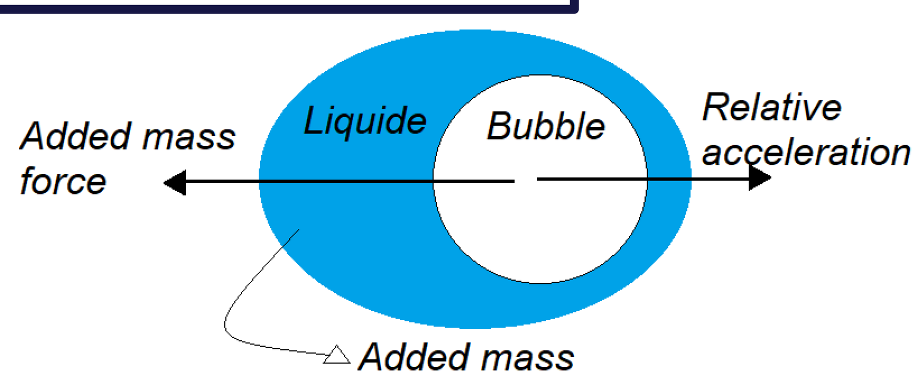
AERATING TURBINES

- The water pumped from the reservoir to the river is often low in dissolved oxygen. The low level of oxygen is harmful to the aquatic life.
- Using aerating turbines is a solution to reduce drastically this impact.
- The aeration process involves injecting air bubbles at the turbine level.



- To develop more efficient and ecological turbines, the mechanics of bubble clouds are essential.

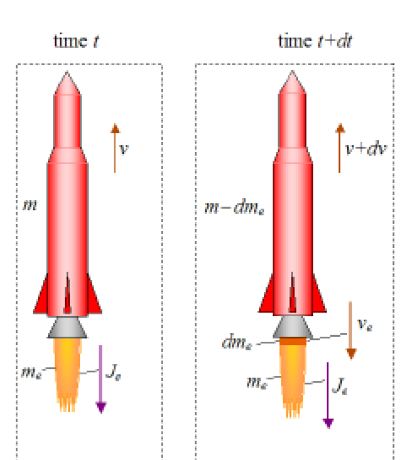
The added mass force



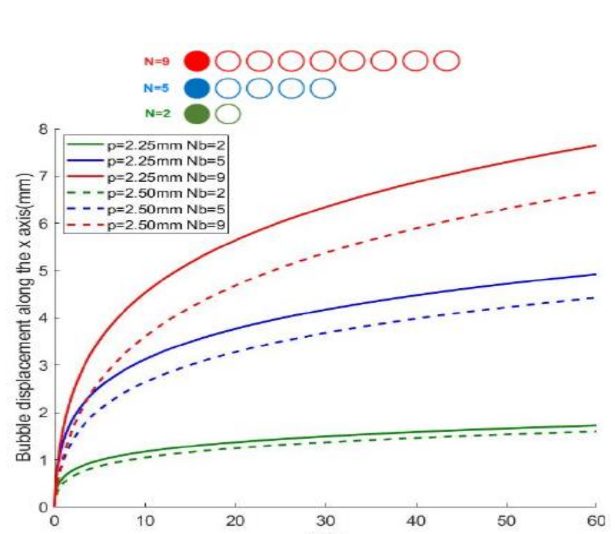
- For two bubbles rising side-by-side, the effects of added mass and induced added mass drive bubbles away from each other.
- The fact that added mass increases as bubbles come closer to each other, create a repelling force.

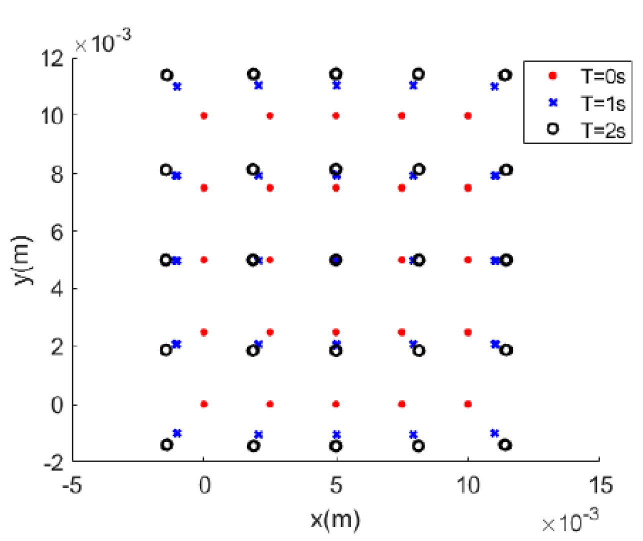
LAGRANGIEN MODELISATION

- The added mass fluctuation is considered as a variable mass problem.
- A **"Meshchersky"** force appears from the spatial variation of the added mass.



The disperssive effect of the "Meshchersky" force

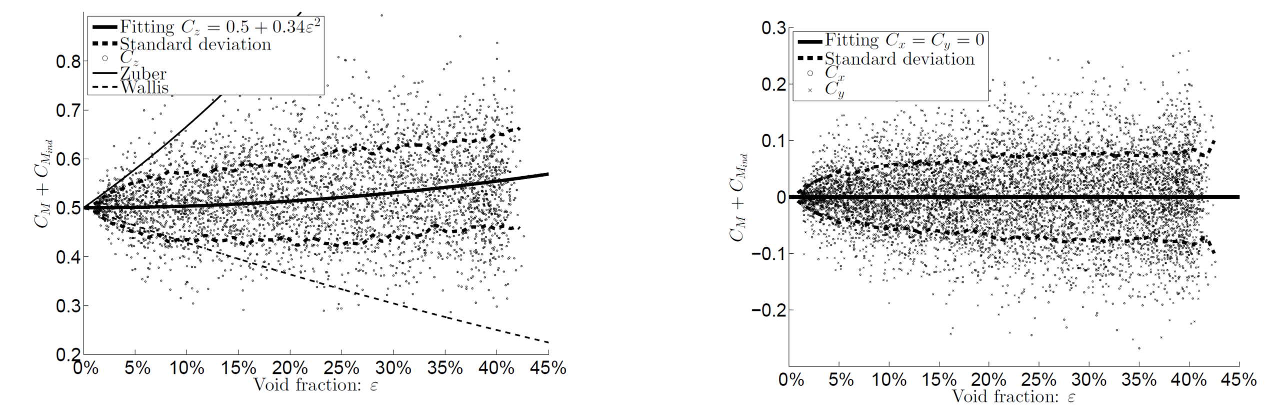




EULERIAN MODELISATION

- Béguin et al. (2016) uses solid harmonics to solve 3D potential flow around bubbles.

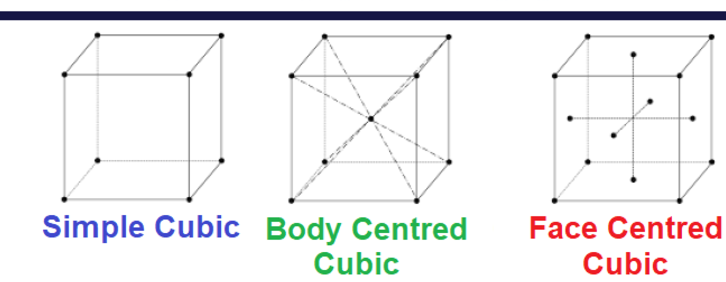
Added mass of the central bubble in a random cloud [Béguin et al. (2016)]



- Actual added mass models do not consider local variations of the added mass due to local bubble distribution.
- The dispersion effect of the "Meshchersky" force cannot be captured.
- **Objective** : To develop a new added mass model for the Eulerian approach that considers local bubble configuration by introducing the void fraction gradient.

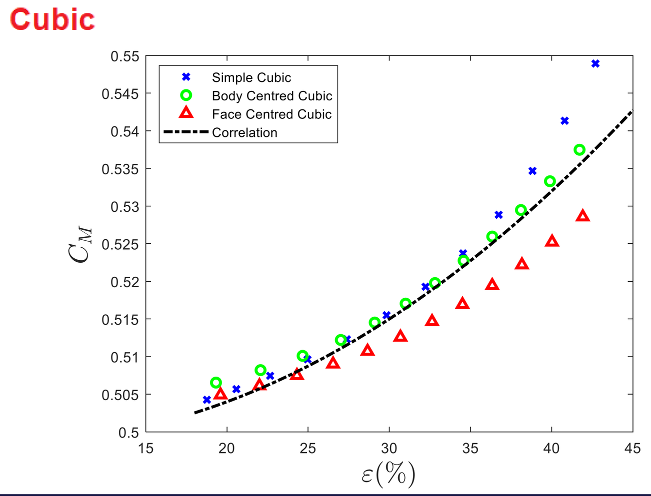
$$\widehat{C}_M = f(\varepsilon, \vec{\nabla}\varepsilon)$$

SYMMETRICAL CONFIGURATIONS



- **Added mass Correlation:**

$$C_M = \frac{1}{2} - 0.04\varepsilon + 0.30\varepsilon^2$$



ASYMMETRICAL CONFIGURATIONS

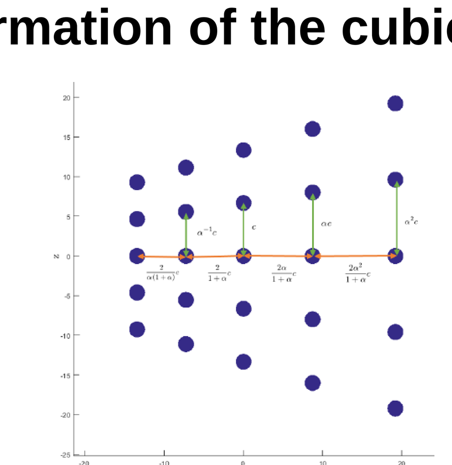
- Uniform transformation for the regular configurations to create a void fraction gradient around the central bubble :

Transformation of the cubic structure

$$x_t = \frac{2c\alpha}{1+\alpha}\,\frac{1-\alpha^{\frac{x_{reg}}{c}}}{1-\alpha}$$

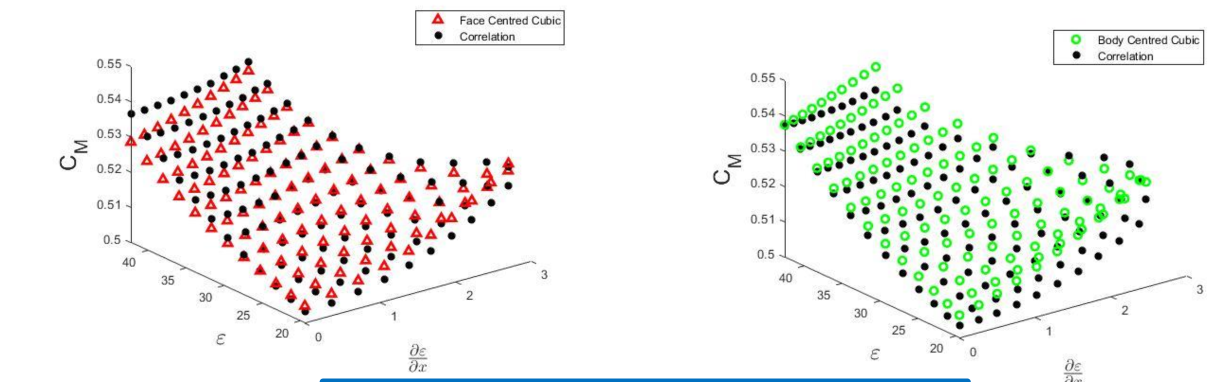
$$y_t = y_{reg}\,\alpha^{\frac{x_{reg}}{c}}$$

$$z_t = z_{reg}\,\alpha^{\frac{x_{reg}}{c}}$$



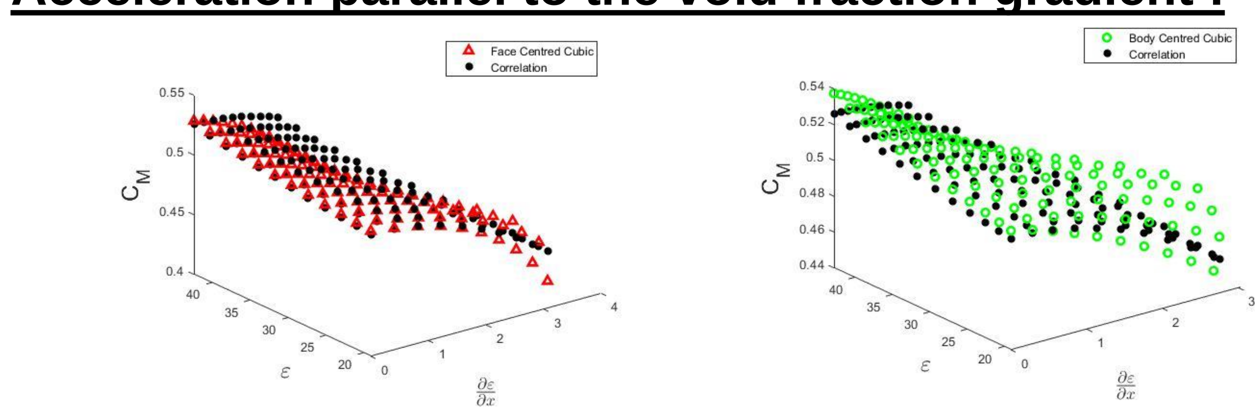
ADDED MASS CORRELATION

- **Acceleration perpendicular to the void fraction gradient :**



$$C_{xx} = \frac{1}{2} - 0.04\varepsilon + 0.30\varepsilon^2 + 24\nabla\varepsilon_{xx}^2$$

- **Acceleration parallel to the void fraction gradient :**



$$C_{zz} = \frac{1}{2} - 0.04\varepsilon + 0.30\varepsilon^2 - 68\nabla\varepsilon_{zz}^2$$

- C_{MT} and C_{MN} are respectively the tangential and normal components of the added mass tensor to the acceleration.
- α is the angle between the acceleration and the void fraction gradient :

$$C_{M_T} = C_{xx} sin\alpha$$

$$C_{M_N} = C_{zz} cos\alpha$$

CONCLUSIONS

- Including the void fraction gradient in the added mass modeling, allows a better representation of its dependence on bubble cloud configuration.
- The fluctuation of the added mass results in a **"Meshchersky"** force that should be included in numerical simulations to model small bubble dispersion.

FURTHER WORK

- Validate correlations with random bubble cloud configurations.
- Develop a **"Meshchersky"** force model for Euler-Euler approach.
- Include the new added mass model in a numerical CFD code to simulate bubble column and transverse bubble jet experiments.

ACKNOWLEDGMENTS

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