Marinization of Bubbling Fluidized Bed Reactors, Visualization, Hydrodynamics, and CFD Simulation

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GPS Génie par la simulation — SBES Simulation - Based Engineering Science

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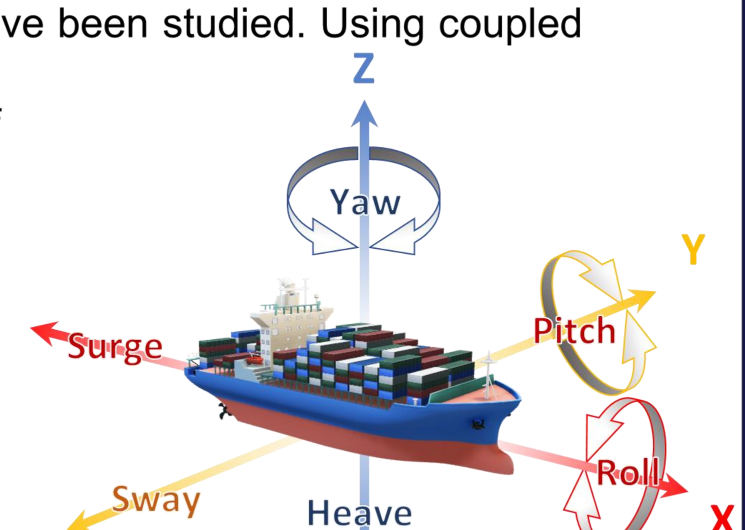
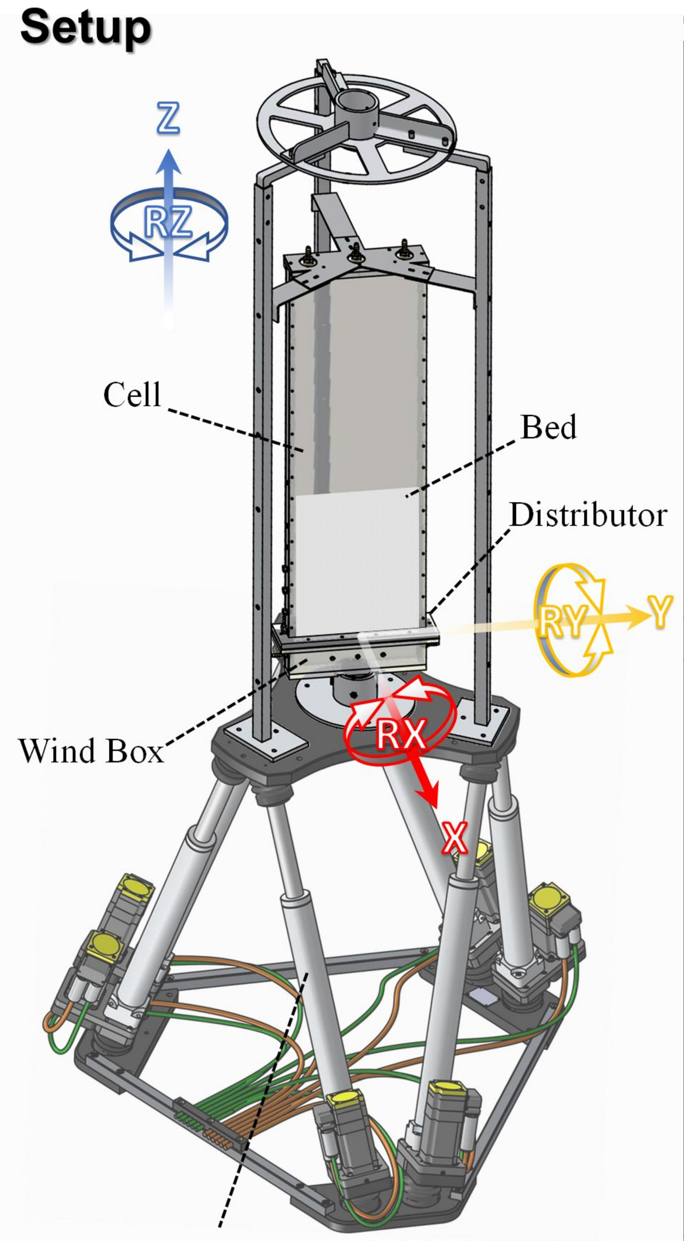
INTRODUCTION

Marine fluidized bed reactors are considered as a potential tool for CO_2, NO_X, and SO_X removal from the ship's exhaust gas. Therefore, harnessing the operation of marine fluidized beds requires efficient modifications to compensate or predict any performance deviation according to the well-trodden land-based fluidized bed technologies. The gravity force usually opposes the direction of fluidization flow except in the inclined pneumatic conveyors used for powder transportation. However, in marine fluidized-bed reactors, verticality of containing vessel relative to gravity changes hectically according to the sea/weather whims resulting in very different dynamics of the forces throughout the bed. Operational instability arises when the forces' direction is thus altered irregularly. Whether the inertial force due to the movement with low amplitude and frequency also has an impact must also be assessed as another source of deviation in harsh sea conditions. It is obvious that it is not possible to study all the required parameters using experimental techniques due to measurement and data acquisition limits. Using modelling and simulation tools facilitate understanding the hidden aspect in our system. In the present study, a 2D fluidized bed with Geldart-B particles has been embarked on a robotized hexapod sea-wave emulator, and the effect of different patterns of motion have been studied. Using coupled Particle Image Velocimetry and Digital Image Analysis technique, the effects of motions on the minimum fluidization velocity, bubble residence time, and local void fraction have been studied. Comparisons show that deviating from verticality in fluidized beds reduces the minimum fluidization point, and changes in bubble characteristics



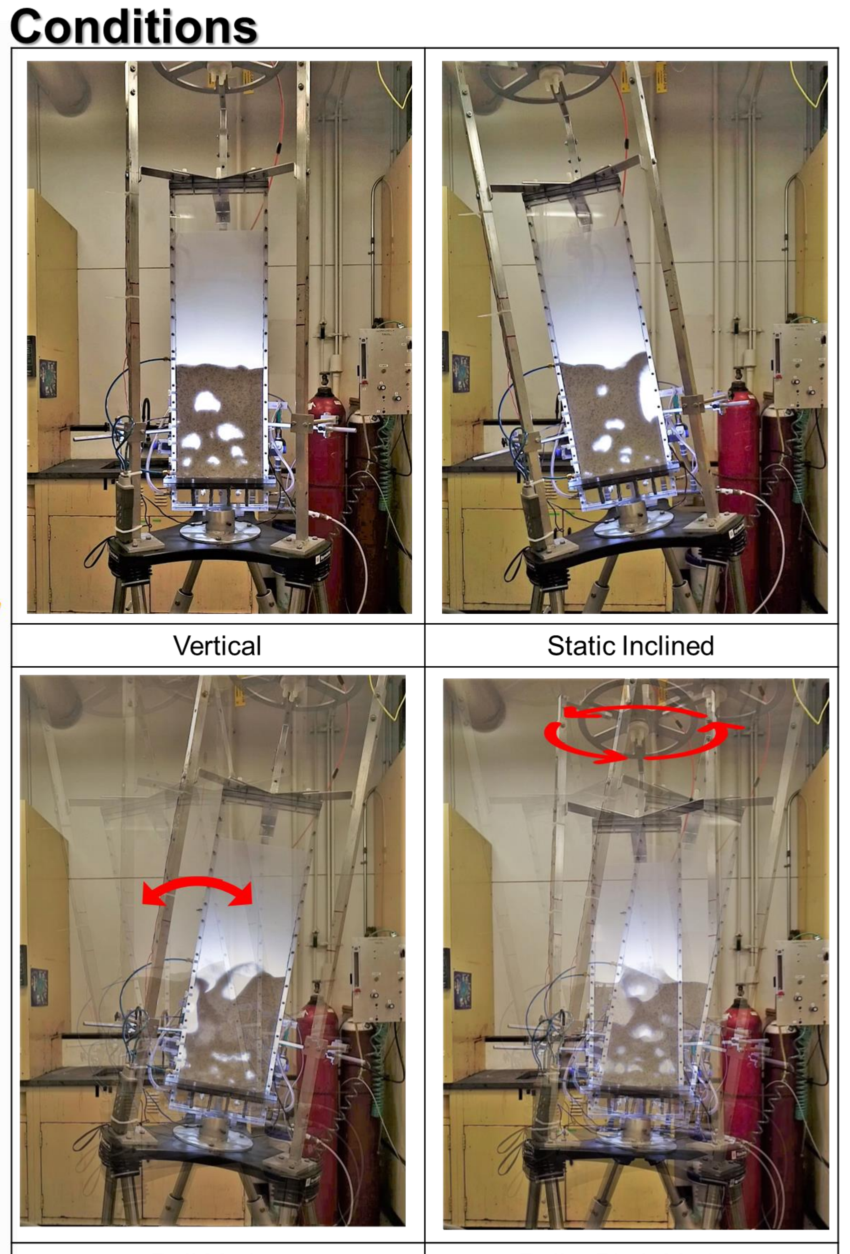
EXPERIMENTAL

Setup



Robotized Marine Swells Emulator

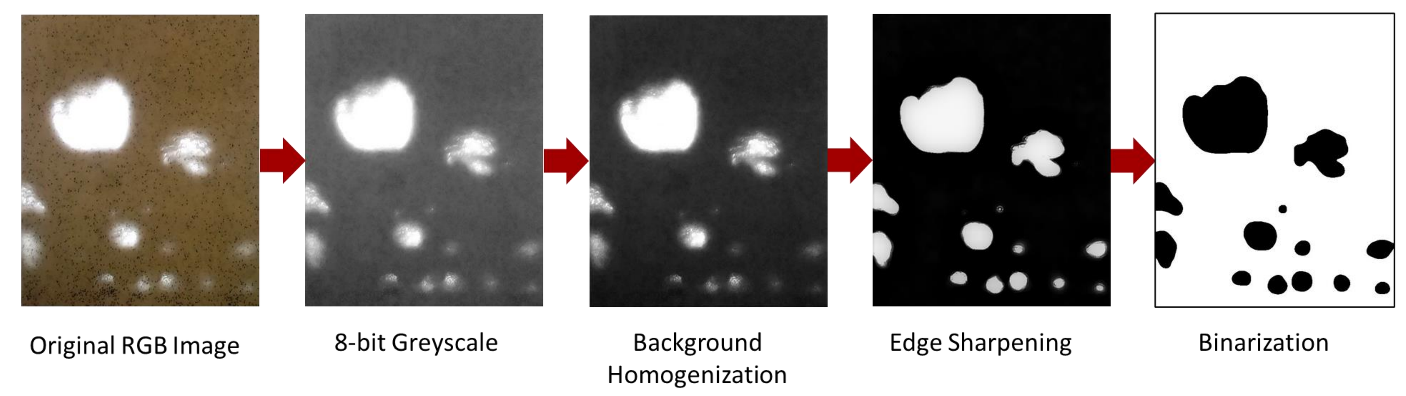
Conditions

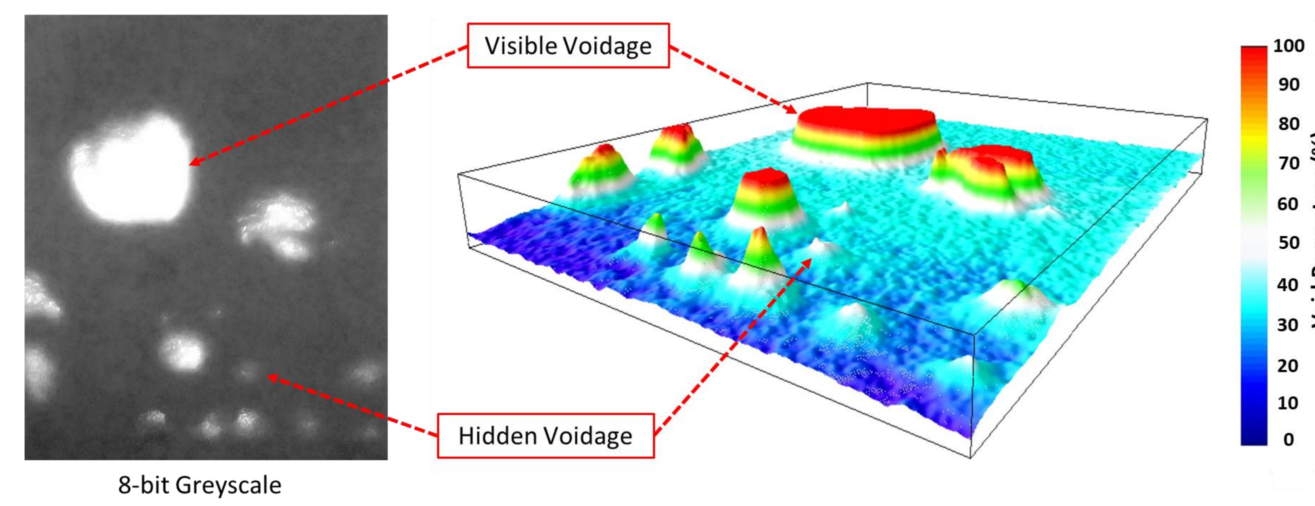


Static Parameters		Oscillation Parameters			
Item	Inclination Angle (°)	Item	Amplitude (°)	Frequency (Hz)	*Phase Lag* (°)
Vertical	0	**Roll**	±3/6/9/12/15	0.05/0.1/0.15/0.2	
Non-Vertical	3/6/9/12/15	**Roll + Pitch**	±3/6/9/12/15	0.05/0.1/0.15/0.2	0+90°

METHODOLOGY

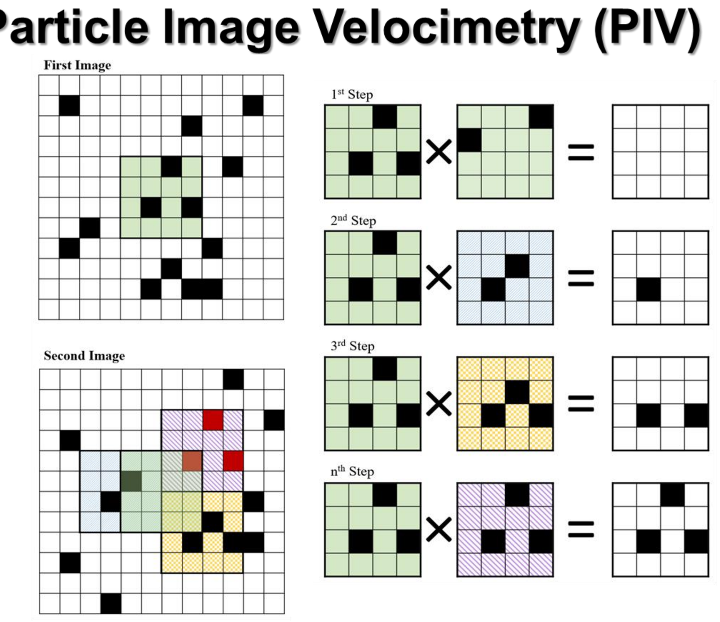
Digital Image Analysis (DIA)



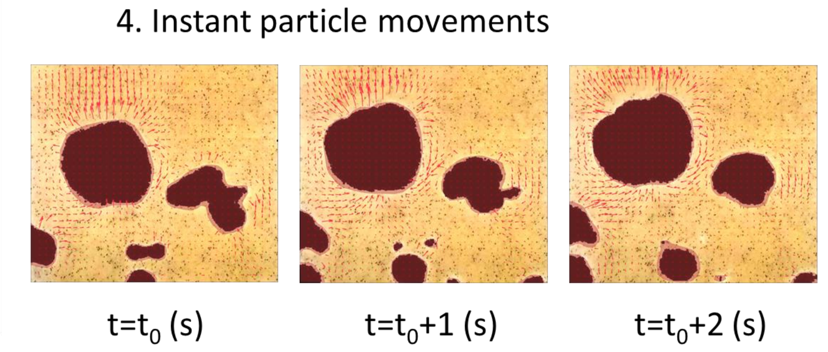


Obtainable information from DIA:
1. Bubble shape 2. Bubble location 3. Bubble rise velocity 4. Coalescence Ratio

Particle Image Velocimetry (PIV)

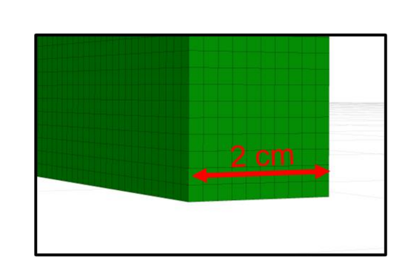


Obtainable information from PIV:
1. Velocity of Particles
2. Trajectory of Particles
3. Mixing of Particles
4. Instant particle movements

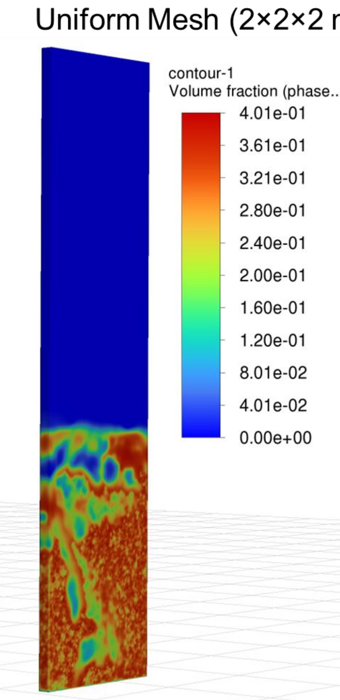


Computational Fluid Dynamic (CFD)

In this work, Eulerian-Eulerian multiphase simulations are planned for the description/prediction of the hydrodynamics of pseudo-2D rolling fluidized bed. The approach assumes a continuum two-phase treatment of the bed consisting of a gas as the primary phase, and a secondary phase for the "solid particles". The latter phase uses Kinetic theory of granular flow (KTGF) to predict the random motion of particles. The simulation approach is not novel in itself but its adaptation to rolling bubbling fluidized beds is to the best of our knowledge new. It will especially attempt to understand the role of inertial forces such as Coriolis, Euler and centrifugal forces as well as the time-varying gravitational and buoyancy forces imposed by the robot oscillations on the bubble dynamics and the solids mixing. Moving reference frame (MRF) method is planed to perform roll motion of fluidized bed. To consider the influence of the robot oscillations on hydrodynamics of the fluidized bed, governing equations should be modified. Fictitious acceleration forces due to the robot motion from the stationary (or vertical) referenced frame to the moving (non-inertial) frame in rotational (roll, roll+pitch), and translational (heave) oscillation should be added to the momentum equation.



Uniform Mesh (2×2×2 mm)



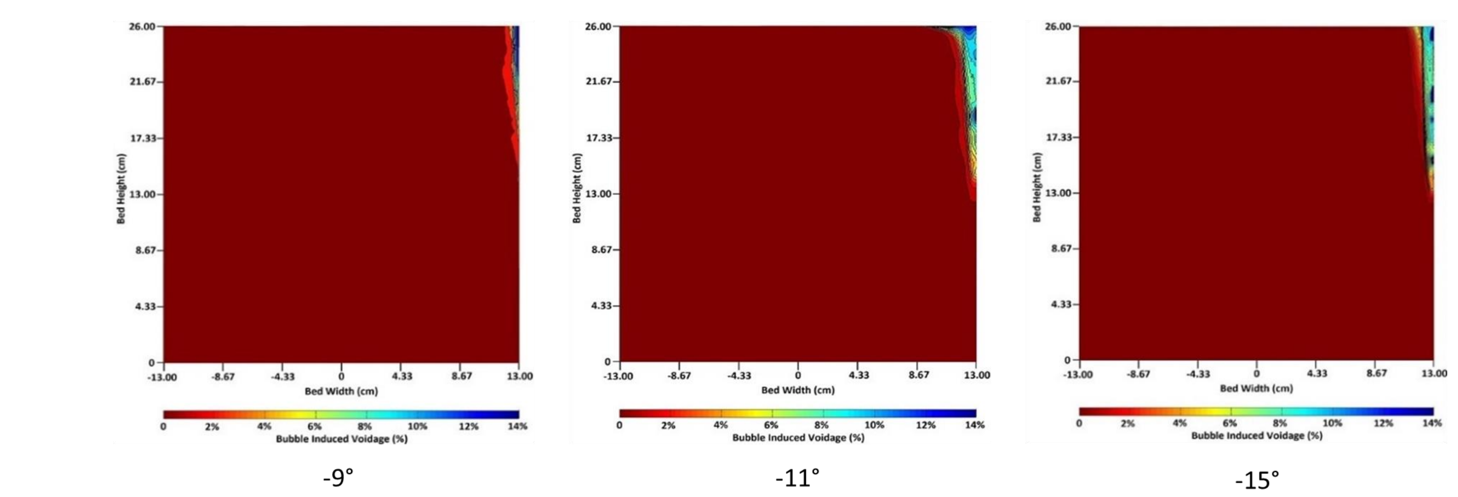
Preliminary Runs

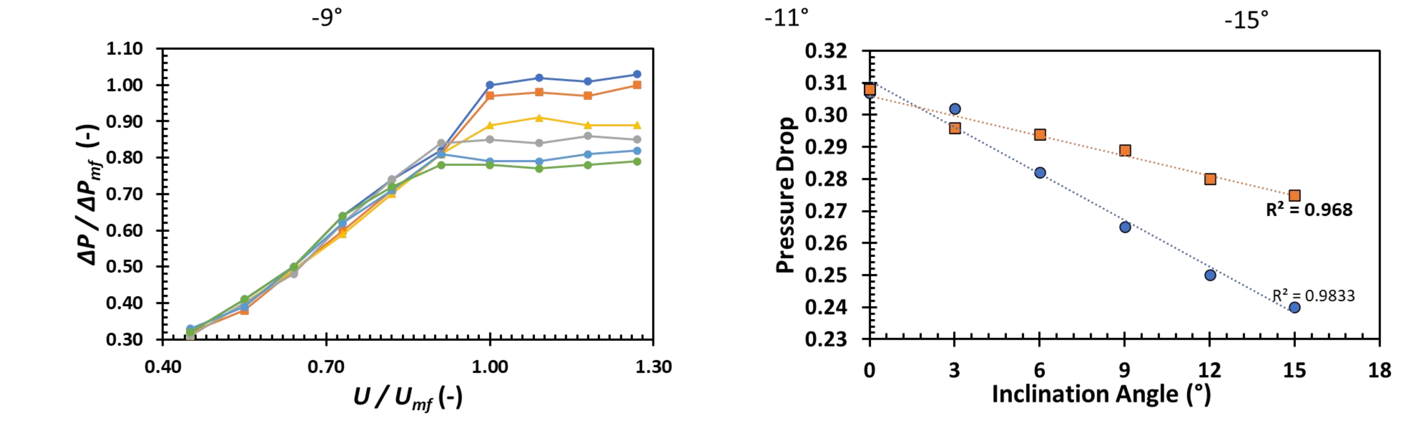
In this model:

-Syamlal-O'brain drag for interphase momentum exchange
-Particulate phase pressure is suggested by Lun et al.
-Kinetic theory of granular flow (KTGF)

RESULTS

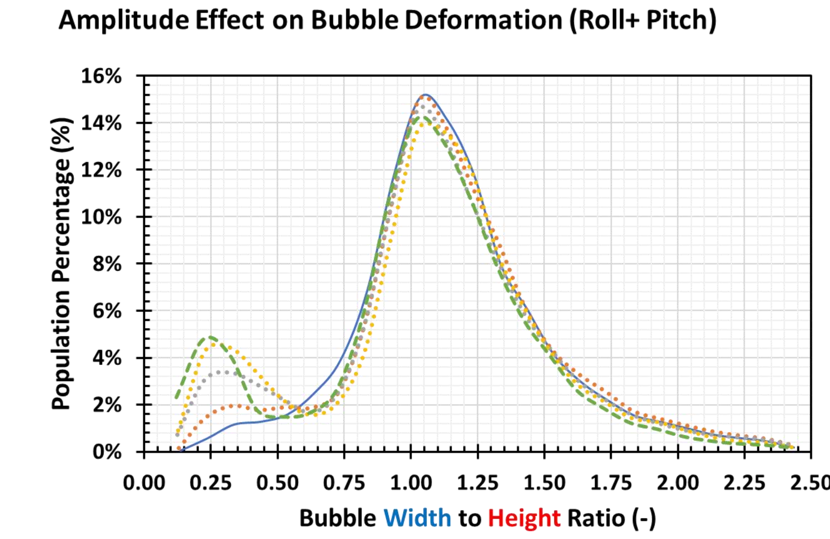
Effect of Inclination on Minimum Fluidization Regime



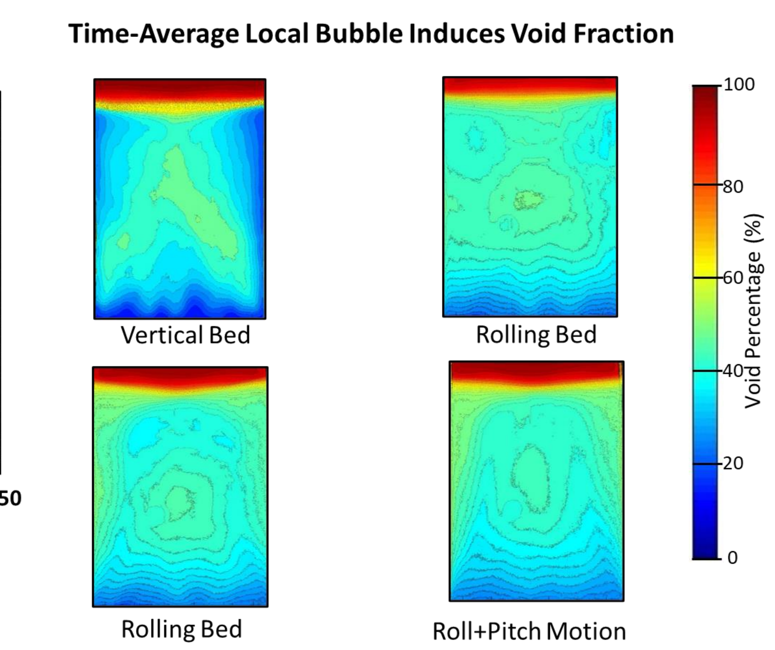


Oscillating Conditions

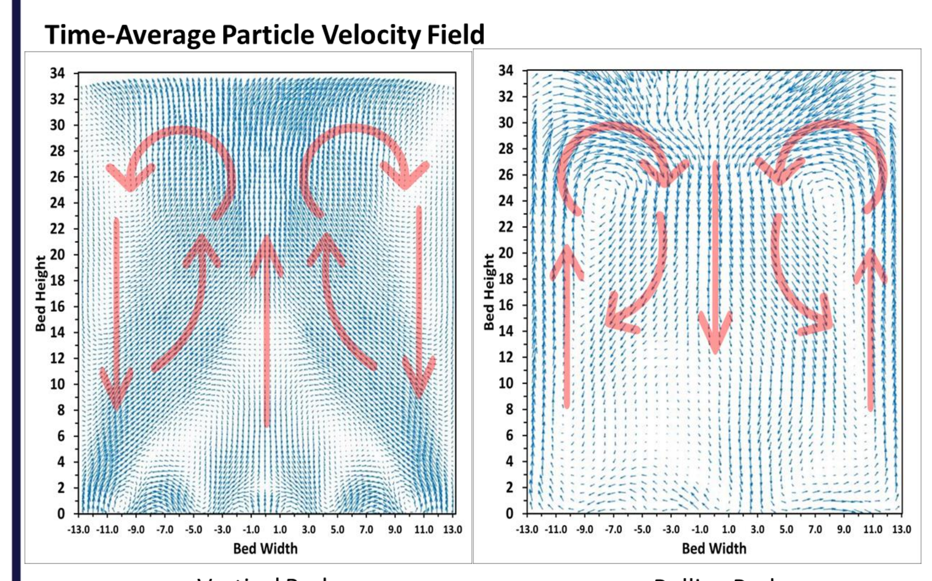
Amplitude Effect on Bubble Deformation (Roll+ Pitch)



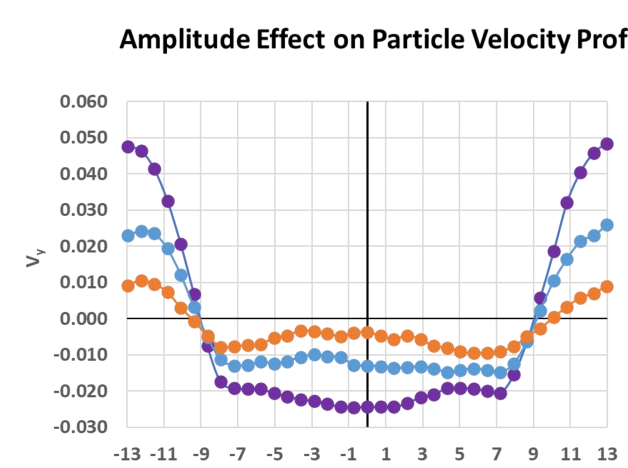
Time-Average Local Bubble Induces Void Fraction



Time-Average Particle Velocity Field



Amplitude Effect on Particle Velocity Profile



CONCLUSIONS

In this project:
- Implementation of Pseudo-2D Fluidized Beds for Ship's Exhaust Gas Treatment
- Sea Waves Effect on Hydrodynamics of Fluidized bed

Originality :
- Study on Compound Motion (Roll + Pitch)
- Studying Bubble and particle phases Simultaneously

Remarks:
- 2D beds Instability are different to pitch component of the compound motion
- Solid back-mixing is triggered by inverted particle trajectories caused by rolling motion

ACKNOWLEDGMENTS

CRSNG NSERC — compute • calcul CANADA — GPS Génie par la simulation SBES Simulation - Based Engineering Science