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ACTAS DEL CONGRESO

V ENCUENTRO DE INGENIERÍA DE LA ENERGÍA DEL CAMPUS MARE NOSTRUM

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Quinta edición del Encuentro orientado a servir de espacio de reunión para tratar las distintas facetas de las aplicaciones de la Energía en los ámbitos académico y profesional, así como de instituciones y empresas en el que compartir trabajos, se muestren avances creando un espacio virtual de debate y reflexión en el que plantear soluciones a los importantes retos que la Sociedad tiene en el ámbito de la Energía, englobado en el ODS-7, *Energía asequible y no contaminante*, desde una vocación tecnológica pero a la vez con sensibilidad social.

Universidad de Murcia

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Del 23 al 26 de noviembre de 2020

NUMERICAL SIMULATION OF THE HEAT TRANSFER PROCESS IN A FLUIDIZED BED WITH AN IMMERSED TUBE

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ABSTRACT

This work aims to perform a numerical simulation of the heat transfer process of an immersed spherical surface in a bubbling fluidized bed. The experimental conditions of Di Natale et al. [1] were numerically reproduced: a hot sphere of 28 mm diameter immersed in a fluidized bed of 600 mm height. The sphere was in the middle of the bed, at a height of 300 mm, and with constant surface temperature of 373 K. The numerical simulation was approximated to a 2-D geometry, with a thickness of the bed of only 15 mm, in which the hot sphere is replaced by a horizontal cylinder resembling a tube. The bed was filled with spherical glass particles with a mean particle diameter of 0.5 mm, which were fluidized with atmospheric air at 293 K and with an air velocity of 0.3 m/s.

The numerical simulations were carried out with the software CPFD-Barracuda, which is based on multiphase particle in cell (MP-PIC) method. This methodology is specific to simulate granular flows and solve the motion of groups of particles called “clouds”. In this way, the computational cost is notably reduced in comparison with a full Lagrangian simulation, in which the motion of all individual particles is solved.

The numerical results permited a detailed analysis of the local heat transfer coefficient between the hot tube and the fluidized bed. Different heat transfer rates were observed around the tube. According to the results, the heat transfer coefficient is high at the bottom and at both sides of the tube (with values close to 200 W/(m^2·K)), where the bubbles motion continuously replaces the heated particles in contact with the tube surface with new cold particles, creating a high heat transfer rate in those regions. In contrast, on the top of the surface, the particles are not fluidized. This was clearly observed in the simulation results: on the top of the tube the resulting particle velocity was close to zero and the particle volume fraction was close to the one at minimum fluidization conditions (0.6). This means that particles on top of the tube are at rest and they are not replaced by new cold particles by the action of the bubbles. Consequently, the heat transfer in this region remains low all the time (with values around 20 W/(m^2·K)).

REFERENCIAS

[1] Di Natale, F., Lancia, A., & Nigro, R. (2007). Surface-to-bed heat transfer in fluidised beds: effect of surface shape. Powder Technology, 174(3), 75-81.

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Numerical simulation of the heat transfer process in a fluidized bed with an immersed tube

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Heat transfer in fluidized beds

Fluidized beds have advantages over packed beds as thermal energy storage systems due to:

- high mixing rates, which allows to rapidly distribute thermal energy over the whole mass of particles
- high heat and mass transfer rates

Objective of the work

In deep analysis of the heat transfer process in an horizontal tube within a bubbling fluidized bed

Numerical modeling of fluidized beds

There are different numerical approaches to simulate the hydrodynamics of fluidized beds:

- **Eulerian approach**: modeling the bubble and the dense phase as two interpenetrating fluids
  - advantages: low computational cost
  - disadvantages: bubbles detection depends on an arbitrary threshold value and defluidized zones are not properly modeled
- **Lagrangian approach**: modeling the motion of each individual particle in the bed.
  - advantages: more detailed results
  - disadvantages: very high computational cost

CPFD-Barracuda: Multiphase-Particle in Cell approach

Model the motion of a group of particles ("*clouds*"), which notably reduces the computational cost compared with modeling the motion of individual particles.

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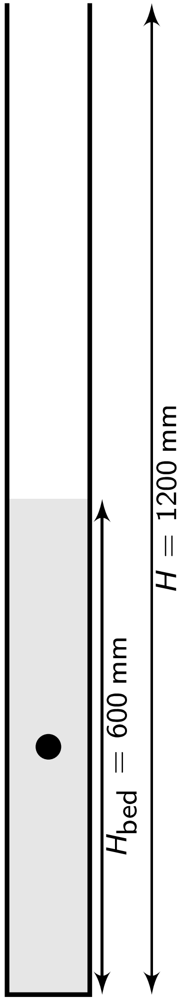
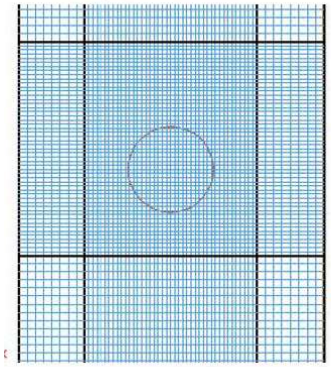
Model set-up: mesh

We reproduce the experimental work of Di Natale et al. (2007).



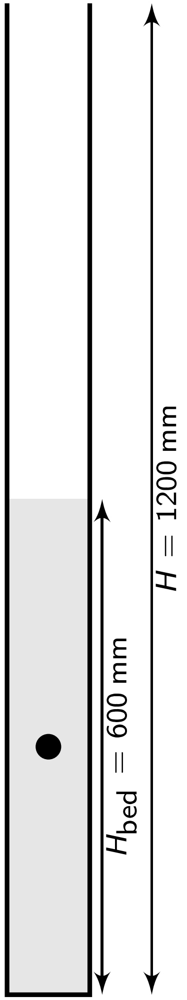
- Spherical probe immersed in the bed: circle of 28 mm diameter
- quasi-2D simulation approach (1.5 cm and 5 computational cells)
- 1.38×10^5 cells and $\Delta t = 10^{-4}$ s, which were previously checked to produce accurate results with a reasonable computational cost.
- Detail of the refined mesh around the cylinder



Model set-up: boundary conditions

We reproduce the experimental work of Di Natale et al. (2007).

Boundary conditions:



- inlet air: uniform temperature ($T_{in} = 293\,\text{K}$) and uniform air velocity ($u_{in} = 0.3\,\text{m/s}$)
- outlet: pressure outlet: $p_{out} = 10^5\,\text{Pa}$
- wall bed temperature: adiabatic
- cylinder temperature: $T_s = 373\,\text{K}$
- initial conditions: $T_{\text{bed}} = T_{in} = 293\,\text{K}$ and particles at rest

The bed was simulated during 60 s and the first 5 seconds were discarded due to the start-up period.

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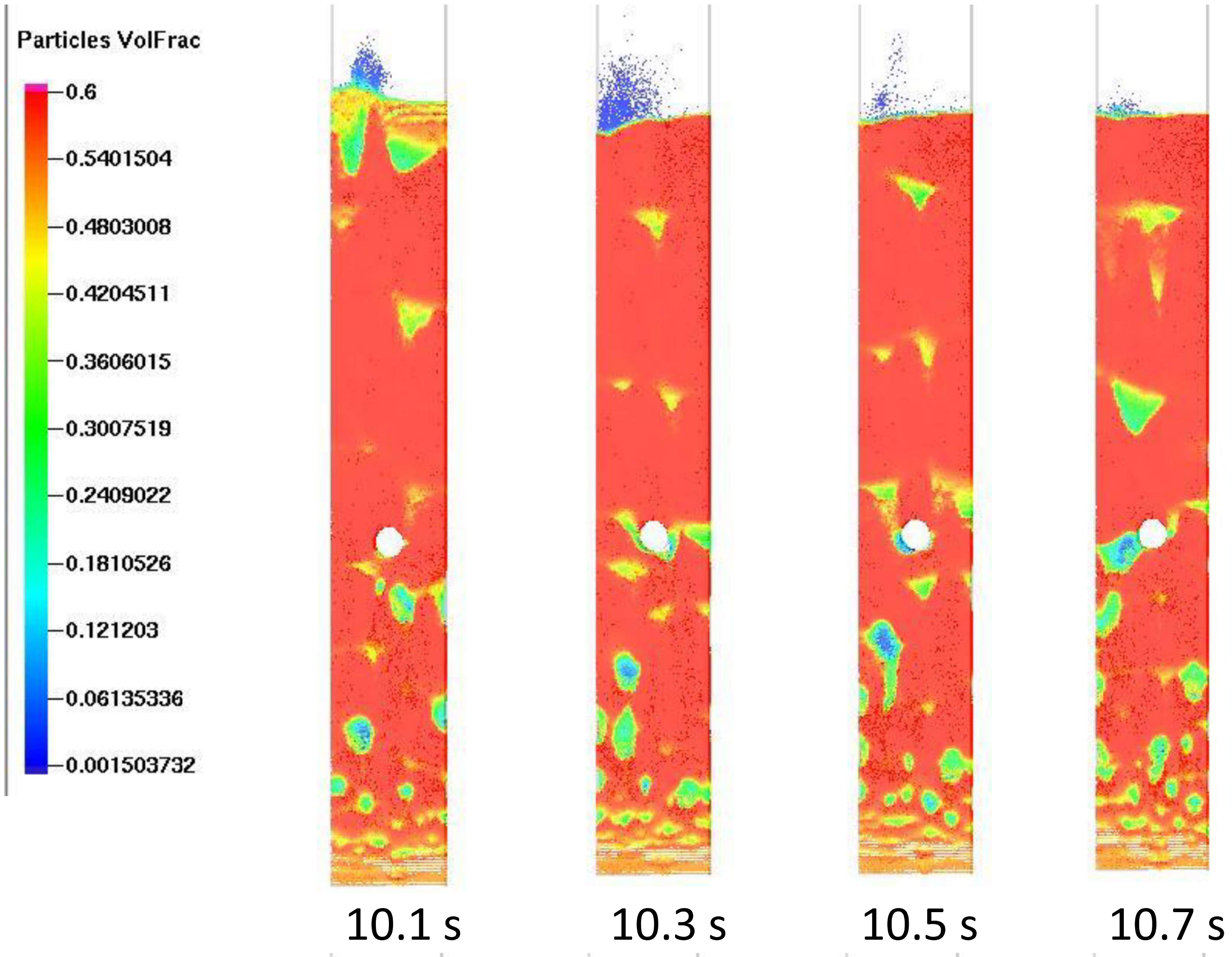
Fluid dynamics: Particle Volume Fraction in the bed

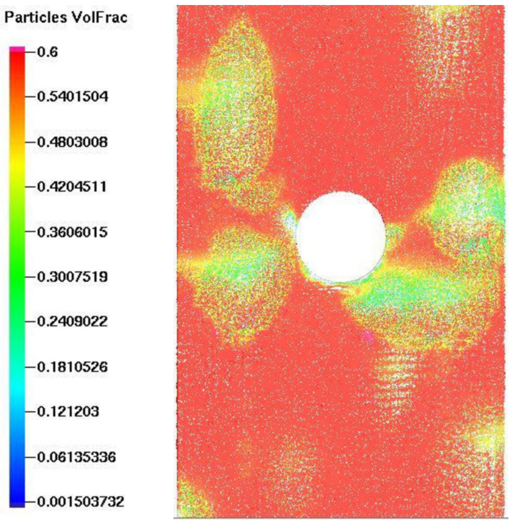
Bubbles motion in the bed



10.1 s   10.3 s   10.5 s   10.7 s

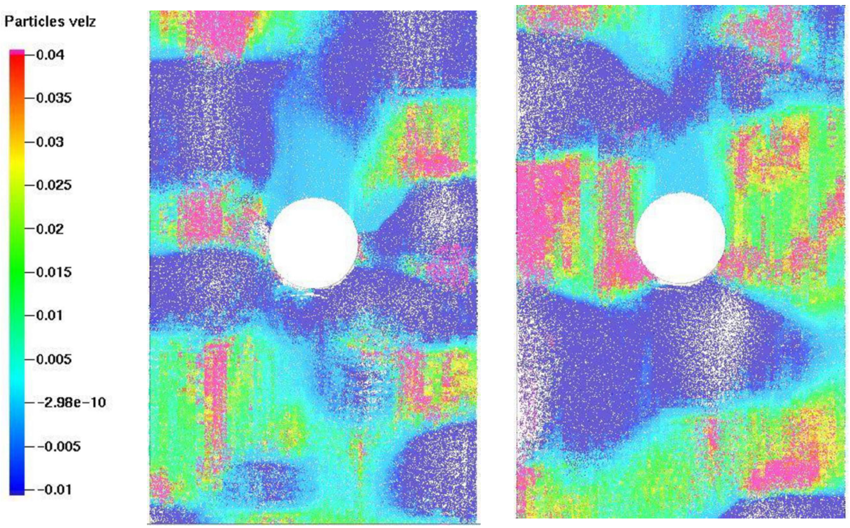
Fluid dynamics: Particle Volume Fraction and velocity close to the tube

Detail of the bubble motion around the immersed tube



20.3 s

24 s



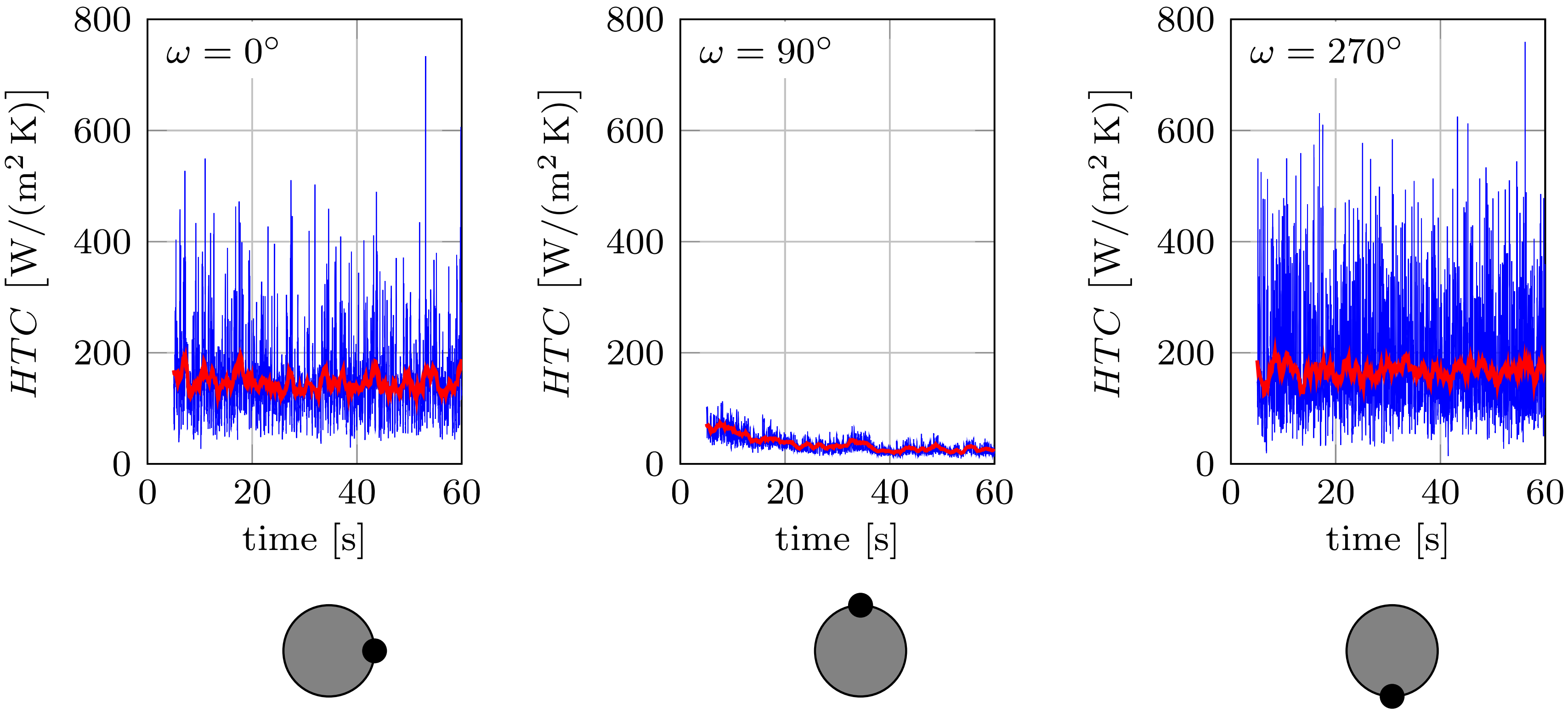
20.3 s

24 s

- Inside the bubbles the particle velocity is low or even negative
- On the top of the tube $u_p = 0\,\mathrm{m/s}$
- Higher particle velocities are observed between bubbles

Heat transfer coefficient (*HTC*) around the tube

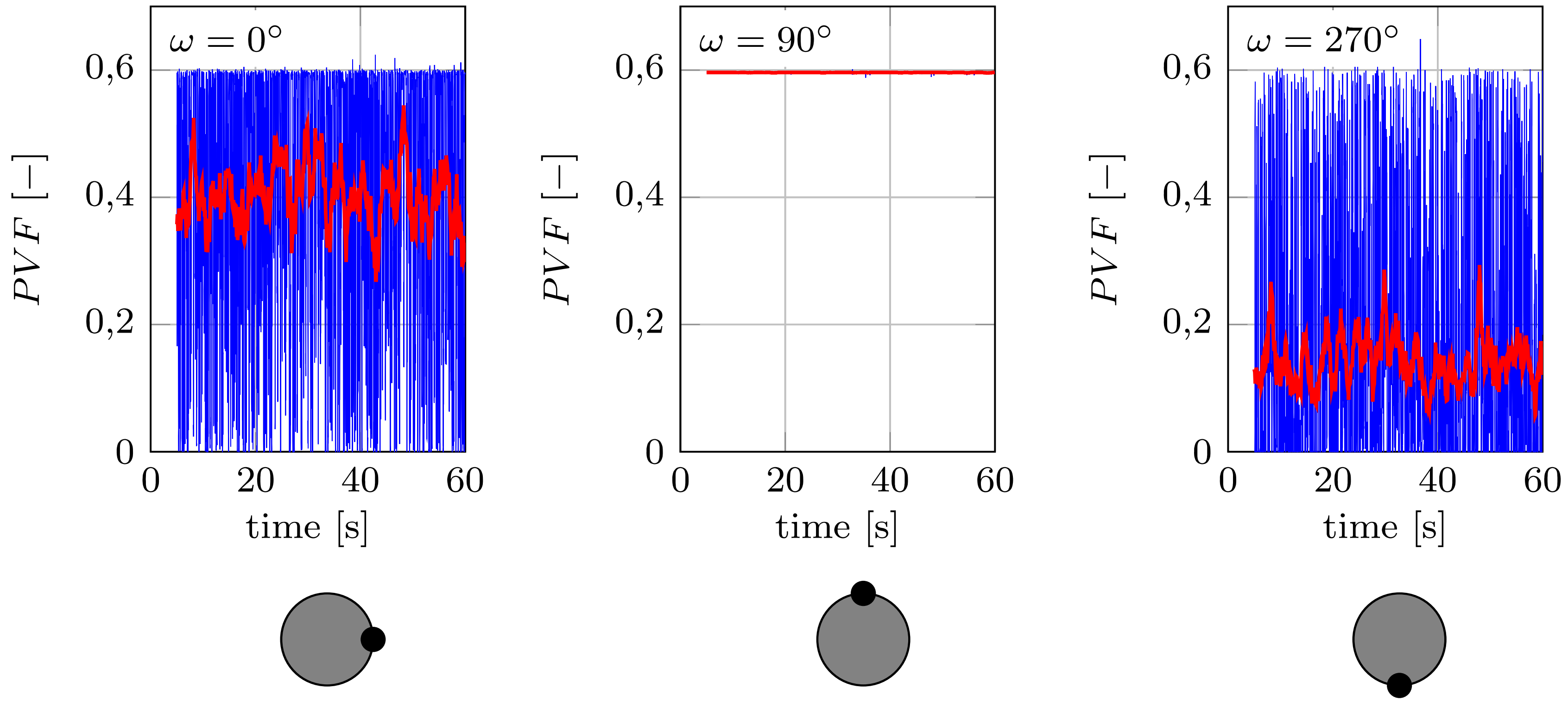
The *HTC* notably varies with the angular position in the tube



On the top of the tube the *HTC* is very low because there is no renovation of particles.

Particle Volume Fraction (*PVF*) around the tube

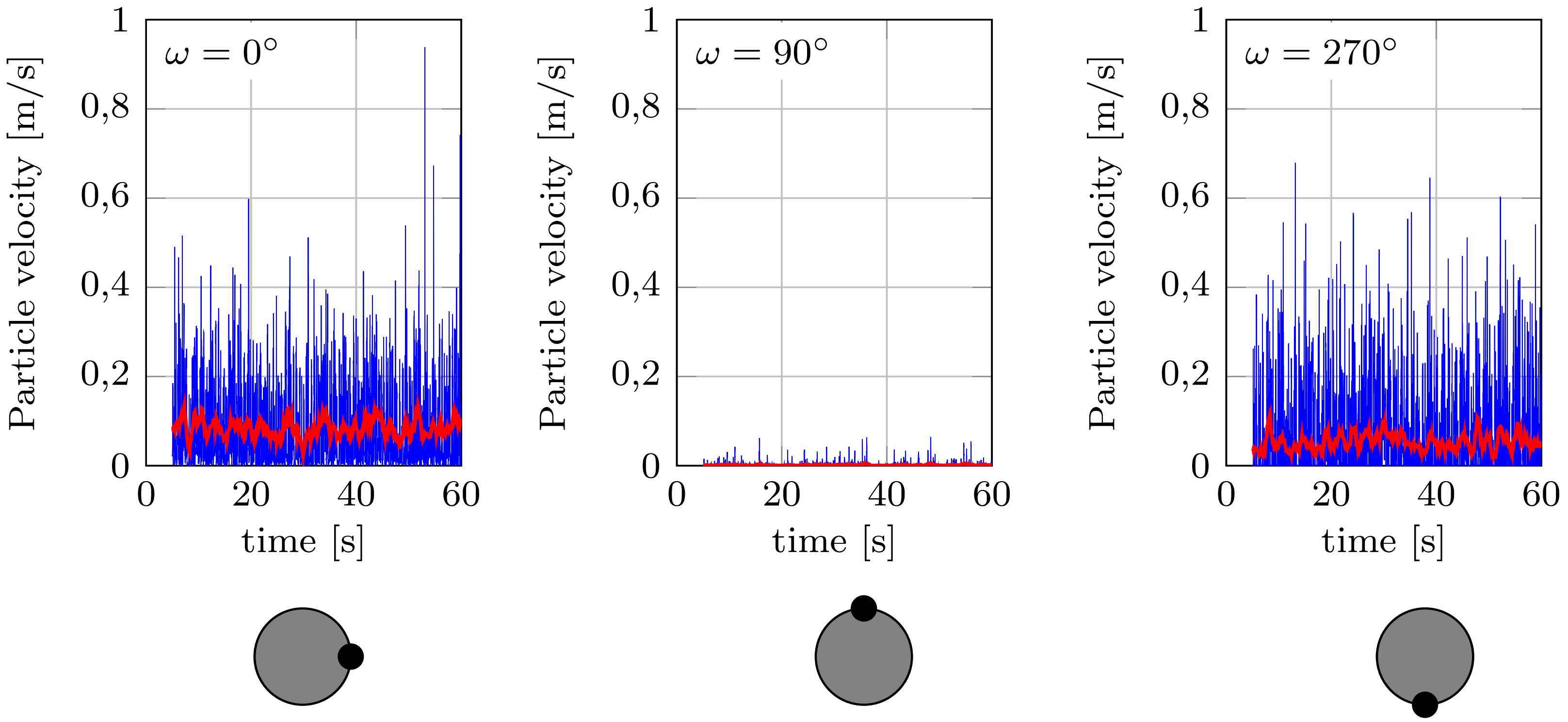
The *PVF* notably varies with the angular position in the tube



On the top $PVF \approx 0.6$ and it fluctuates at the bottom and at the side of the tube.

Particle velocity ($\vec{u}_p$) around the tube

The particle velocity notably varies with the angular position in the tube



On the top $|\vec{u}_p| \approx 0$ (indicating defluidization) and it fluctuates at the bottom and at the side of the tube.

Conclusions and future works

- The HTC notably varies around the tube, and it is influenced by the particle velocity and PVF
- Bubbles around the tube provoque fluctuations of the HTC
- Future works:
    - 3-D simulations
    - Simulations of a bank of tubes

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