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Ingeniería de la Energía

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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.

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TEMPERATURE DISTRIBUTION IN TWO DIFFERENT FLUIDIZATION TECHNOLOGIES APPLIED TO DIRECTLY IRRADIATED FLUIDIZED BEDS

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ABSTRACT

This work aims to compare two different fluidization technologies (bubbling and spouted beds) applied to directly irradiated fluidized beds, when both operate at similar conditions (mass of solid particles, airflow rates, radiation fluxes and medium bed particle heights). In both cases, the fluidized bed is irradiated from the top of the bed with a beam-down reflector with a 4 kW Xenon lamp working at 2 kW. There are different solid particles that can be used in fluidized beds. However, according to previous works [1], the most suitable material due to their optical properties is Silicon Carbide. Therefore, 7 kg and 10 kg of this material was necessary for spouted and bubbling beds, respectively. These masses of particles were exposed to similar radiation conditions from an optical point of view, using the same focal length between the top of the bed in both cases (L_{focal}=1.29 m).

The bubbling fluidized bed consists of a cylindrical geometry with an inner diameter of 31.5 cm. In this technology, the airflow passes homogeneously though the cross-sectional area of the bed and is supplied into the bed through a distribution plate with 89 holes at the lowest part, which separates the particles from the plenum. By contrary, spouted bed has a conical geometry with a bottom diameter of 10.8 cm, which corresponds to the inlet air diameter, and a top diameter of 31.5 cm. The movement of particles in each case is completely different due to the internal geometry. Bubbling fluidization presents particles agitation in the whole of the bed while in spouted bed case two clear regions are distinguished: the central or core region of the bed, where the voidage is very high, and the annular region around the jet. On the top of the spouted bed a form similar to a "fountain" appears, where the particles conveyed from the central jet are projected onto the top of the annular region. In this annular region, the particles move down slowly, while part of the gas percolates through the particles in a countercurrent configuration [2]. The results show how the spouted bed gets a similar behavior to the bubbling fluidized bed but only requiring one-third of its pumping costs, additionally, the thermal energy distribution in the center and periphery of the bed surface presented a behavior completely different. Furthermore, in both cases, higher airflow rates increase the mean temperature in the bed surface.

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[2] Díaz-Heras, M., Moya, J. D., Belmonte, J. F., Córcoles-Tendero, J. I., Molina, A. E., & Almendros-Ibáñez, J. A. (2020). CSP on fluidized particles with a beam-down reflector: Comparative study of different fluidization technologies. *Solar Energy*, *200*, 76-88.

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Temperature distribution in two different fluidization technologies applied to directly irradiated fluidized beds

1

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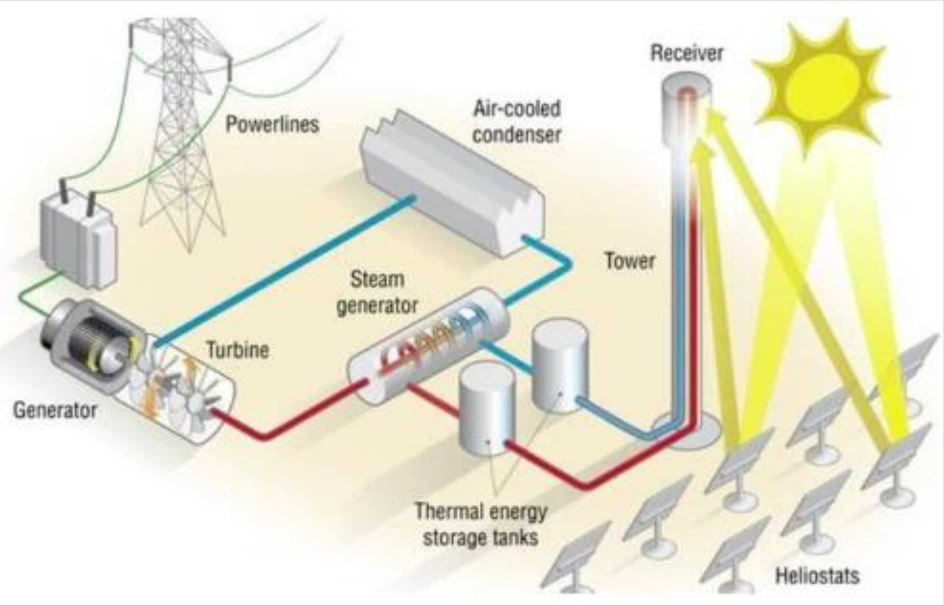
1. INTRODUCTION

- Currently, the efficiency of the power cycle in CSP is limited due to the limit of the maximum temperature in the Heat Transfer Fluid:
  - Thermal oil: $T_{Max} \approx 400°C$
  - Molten salts: $T_{Max} \approx 565°C$

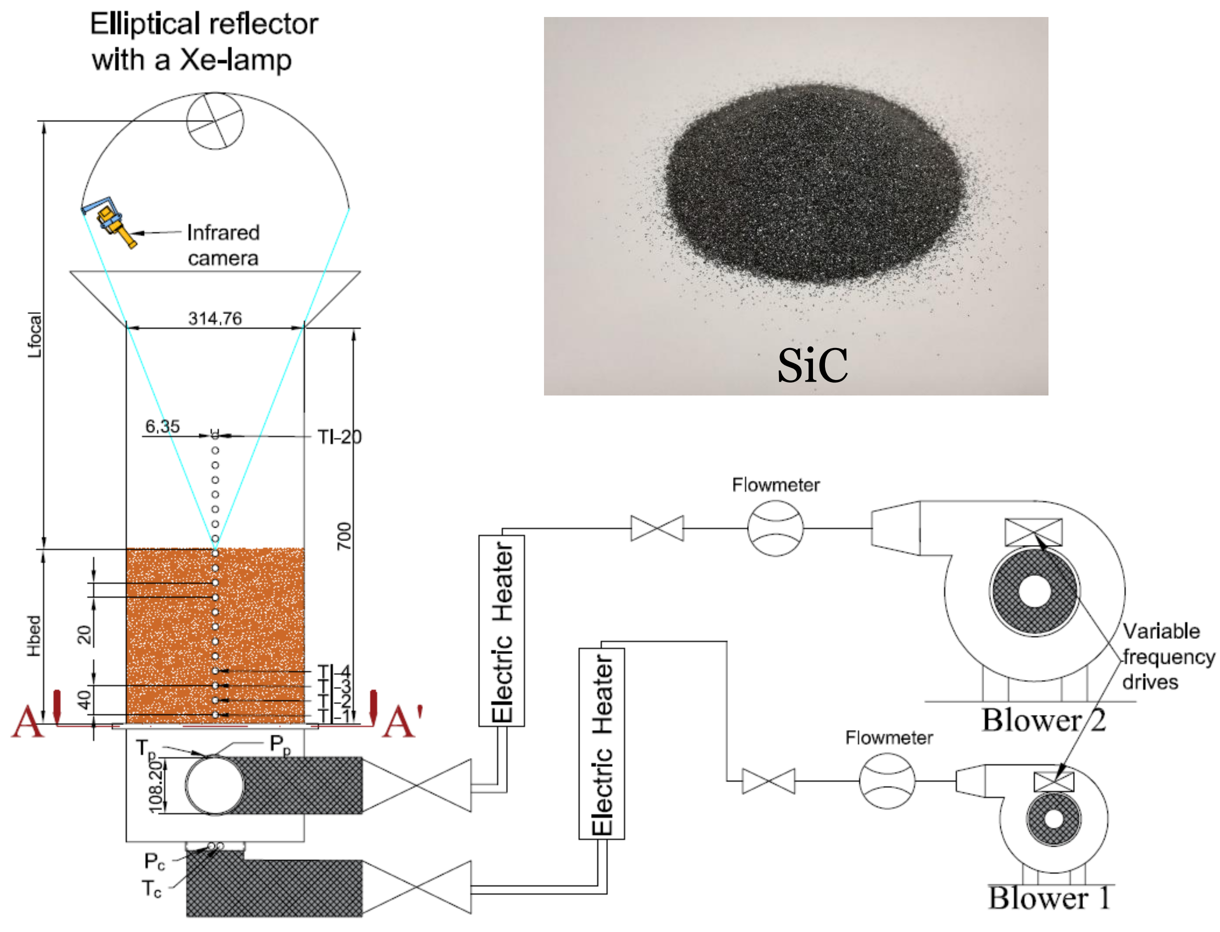
- The use of solid particles permits to increase this temperature up to $T_{Max} \geq \mathbf{1000}°C$



2. AIMS

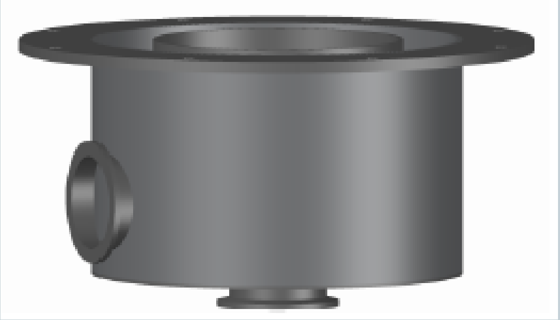
- To study the **thermal energy distribution** on the bed surface of a fluidized bed directly irradiated.
- To identify the advantages and disadvantages of **two different fluidization technologies**: spouted and bubbling fluidized beds.
- To determine the temperature **influence** varying airflow rates in each technology.

3. EXPERIMENTAL SET-UP



A-A' spouted bed

A-A' bubbling bed



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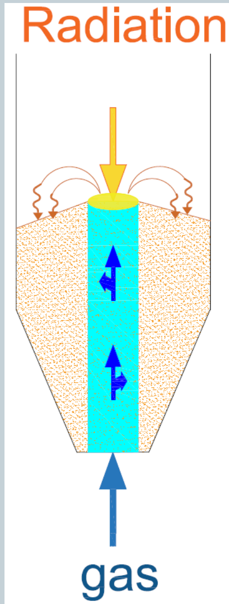
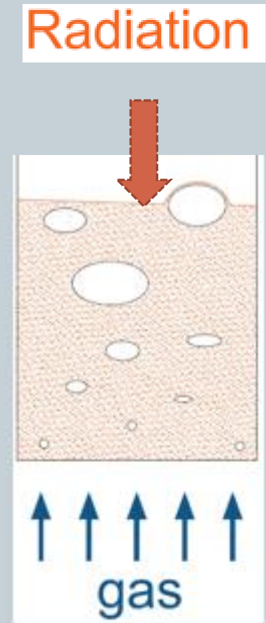


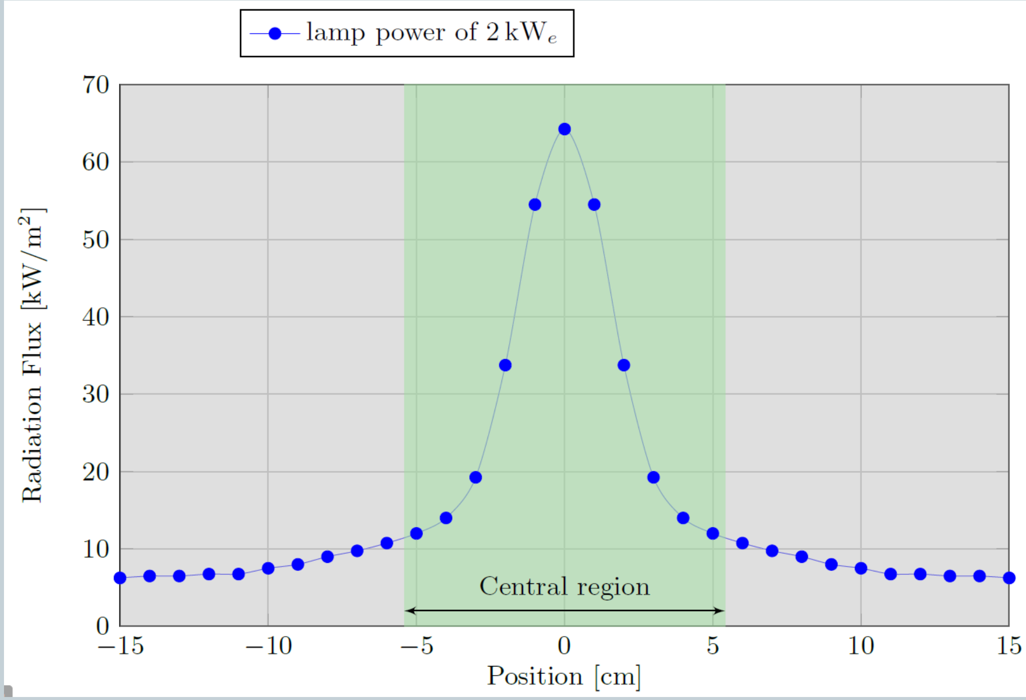


spouted bed

bubbling bed

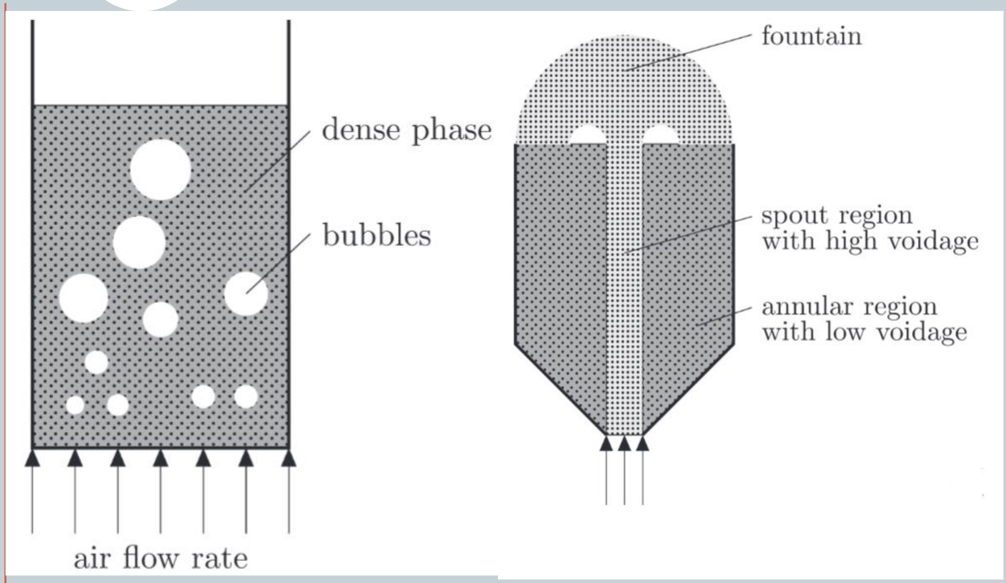
4. METHODOLOGY

1. Characterization of radiation flux



4. METHODOLOGY

1. Characterization of radiation flux
2. Obtain U_{ms}, U_{mf}
3. Test stages for each technology



$\dot{V}_{mf}$=1125 l/min

$\dot{V}_{ms}$=460 l/min

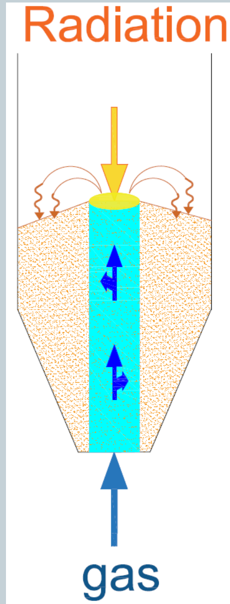
U_{mf}=0.24 m/s

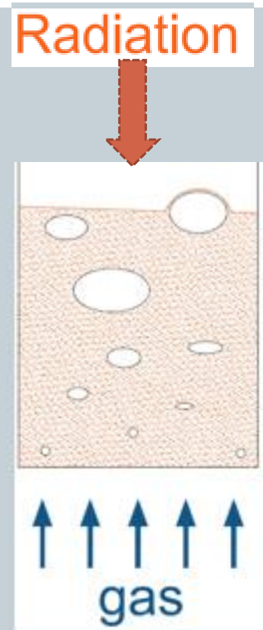
U_{ms}=0.98 m/s

4. METHODOLOGY

Stages

I → fixed bed-15 min
II→ $0.5 \cdot U_{ms}$ - 5 min
III→ $1.025 \cdot U_{ms}$ - 5 min
IV→ $1.075 \cdot U_{ms}$ - 5 min
V→ $1.15 \cdot U_{ms}$ - 5 min





Stages

I → fixed bed-15 min
II→ $0.5 \cdot U_{mf}$ - 5 min
III→ $1.00 \cdot U_{mf}$ - 5 min
IV→ $1.25 \cdot U_{mf}$ - 5 min
V→ $1.50 \cdot U_{mf}$ - 5 min

spouted bed

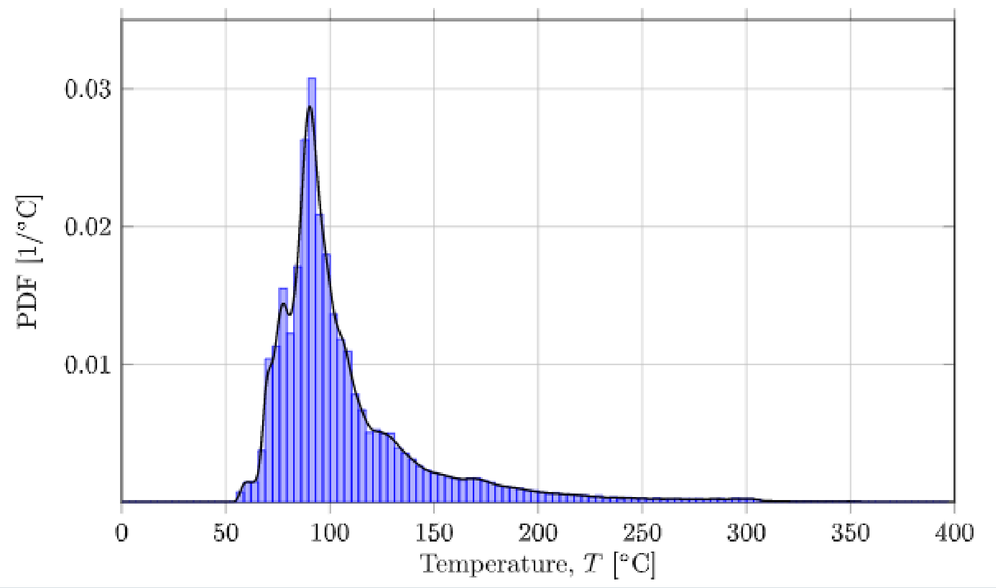
bubbling bed

4. METHODOLOGY

1. Characterization of radiation flux
2. Obtain U_{ms}, U_{mf}
3. Test stages for each technology
4. **Probability Density Function (PDF) of temperature**

- 30 seconds /stage → 7 snapshots
- Under steady state conditions

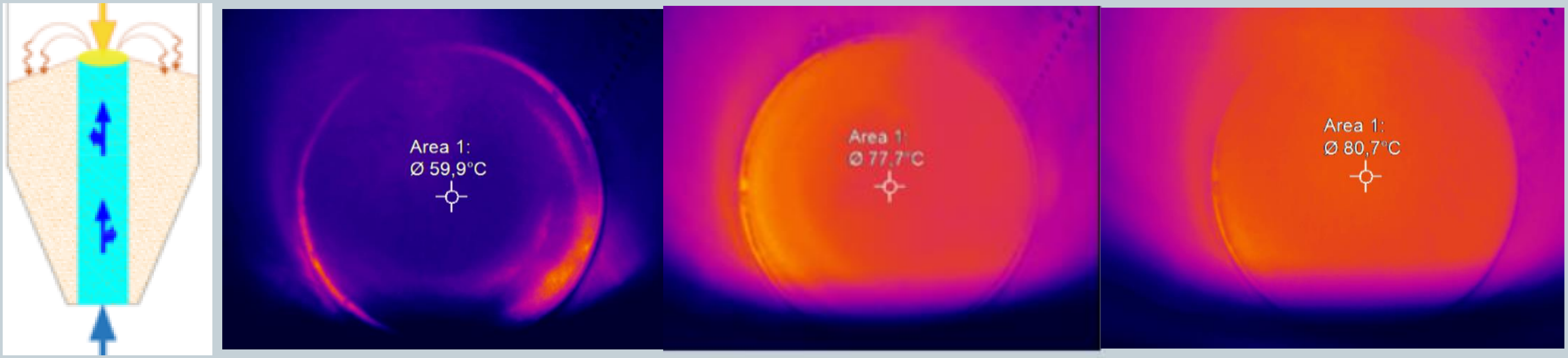
$$\text{PDF} = \frac{dF(T)}{dT}$$



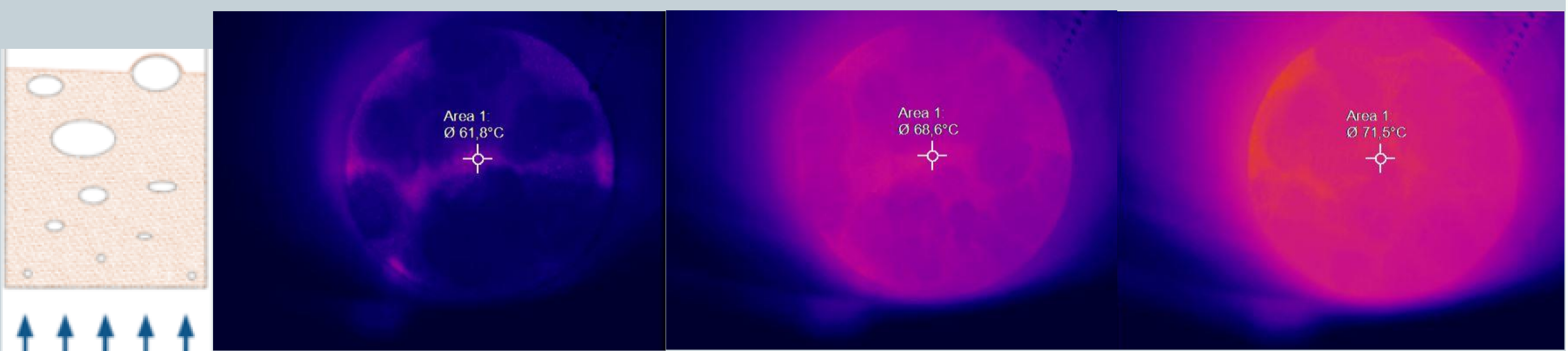
- PDF adjusted to a Kernel distribution

5. RESULTS

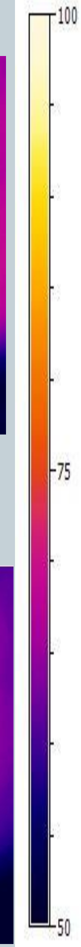
FLUIDIZED BED



$U/U_{ms} = 1.025$ $U/U_{ms} = 1.075$ $U/U_{ms} = 1.15$

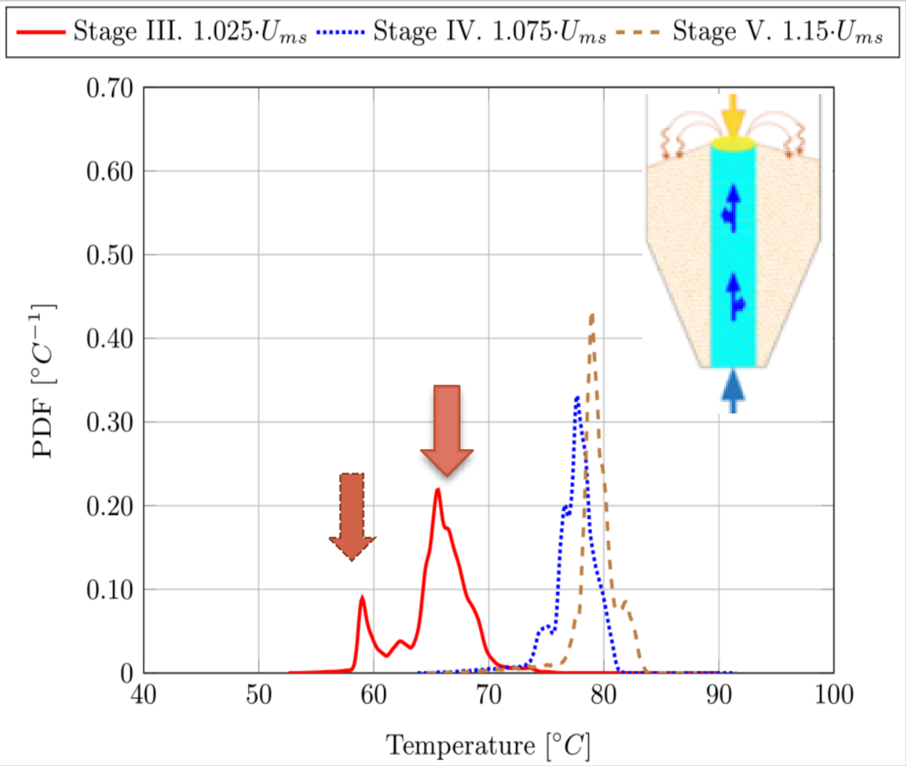


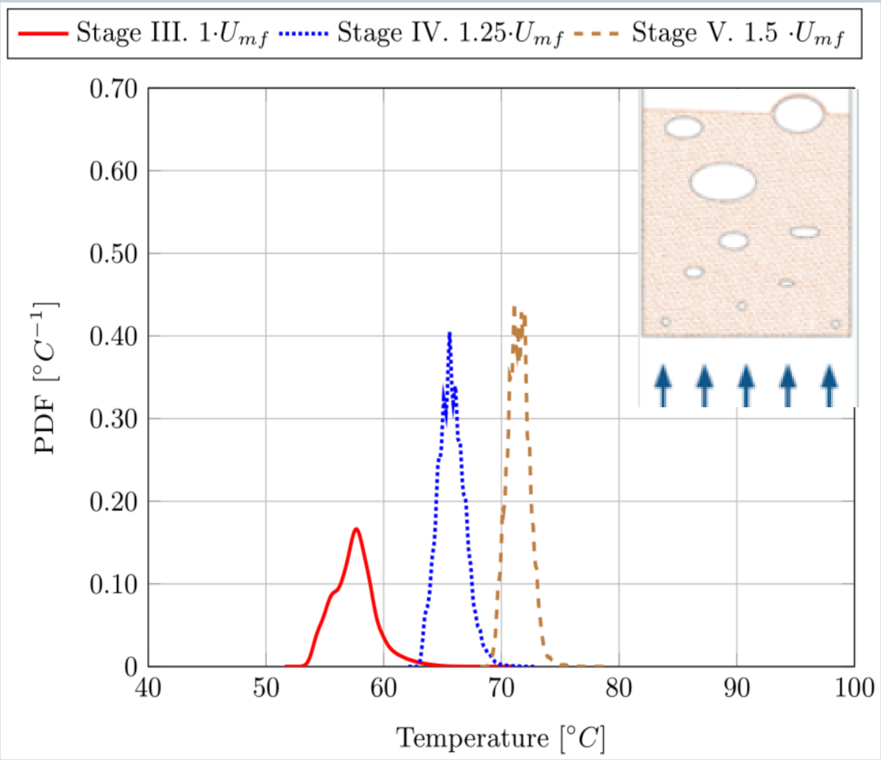
$U/U_{mf} = 1$ $U/U_{mf} = 1.25$ $U/U_{mf} = 1.5$



5. RESULTS

FLUIDIZED BED



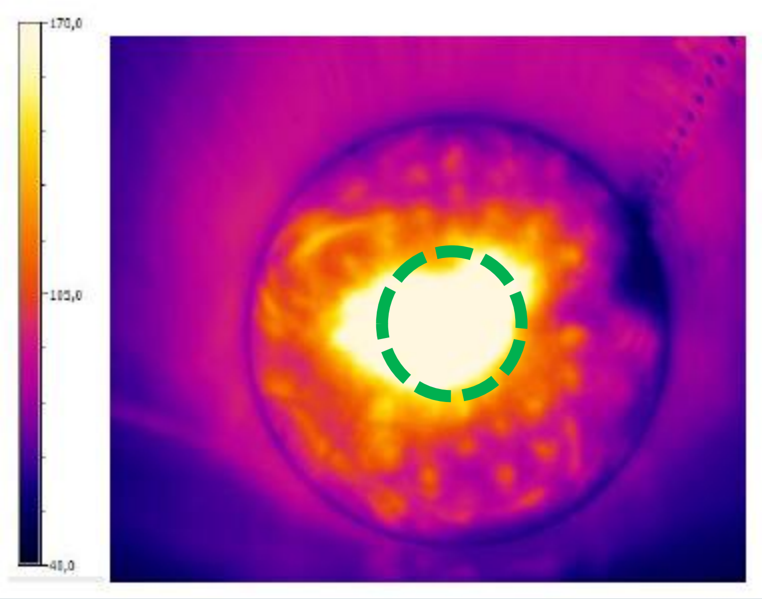


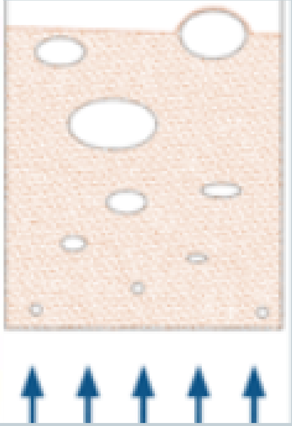
Airflow rate ↑↑ Temperature ↑↑

5. RESULTS

PACKED BED

Center→ T_c
and
Periphery→ T_p





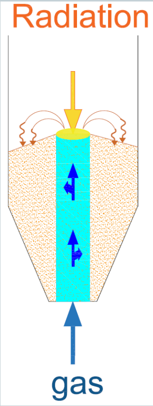
Bubbling $U/U_{mf} = 0.5$

5. RESULTS

Spouting bed

Stage	U/U_{ms}	T [ºC]	σ [ºC]
I	0	173.80	936.81
II	0.5	177.01	465.74
III	1.025	65.33	9.68
IV	1.075	77.43	3.84
V	1.15	79.26	3.87

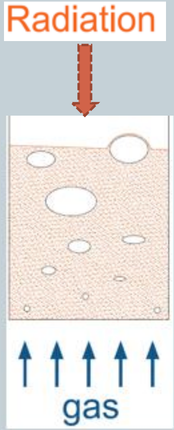
530 l/min



Bubbling fluidized bed

Stage	U/U_{mf}	T [ºC]	σ [ºC]
I	0	193.6	50.3
II	0.5	80	29.6
III	1	57.5	1.8
IV	1.25	65.8	1.16
V	1.5	71.4	0.9

1680 l/min

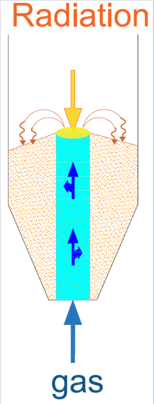


5. RESULTS

Spouting bed

Stage	U/U_{ms}	T_{mean}[ºC]	T_c [ºC]	T_p [ºC]
I	0	173.80	215.07	173.44
II	0.5	177.01	182.87	175.24
III	1.025	65.33	64.64	66.53
IV	1.075	77.43	77.17	77.51
V	1.15	79.26	79.32	79.24

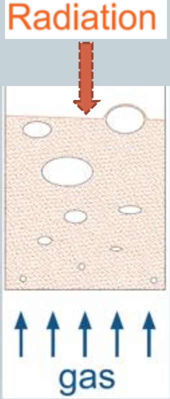
$T_p \geq T_c$



Bubbling fluidized bed

Stage	U/U_{mf}	T_{mean}[ºC]	T_c [ºC]	T_p [ºC]
I	0	193.6	325.31	190.83
II	0.5	80	169.64	77.27
III	1	57.5	60.34	57.44
IV	1.25	65.8	67.38	65.74
V	1.5	71.4	72.89	71.42

$T_c >> T_p$



6. CONCLUSIONS

- Both cases, in Fluidized bed, when Airflow rate ↑↑ Temperature ↑↑
- Mean temperature in spouted bed is slightly higher than in bubbling fluidized bed: $T_{Spouted} > T_{Bubbling}$
- To reach similar values of mean temperature in the bed surface:
  - Pumping costs for bubbling bed are **~3** times higher than in the spouted bed
- Fluidization conditions:
  - Spouted bed $T_p \leq T_c$
  - Bubbling fluidized bed $T_p \gg T_c$
- This work is a previous step to analyse diferent spouted bed configurations for future works.

7. FUTURE WORKS

- Following tests:
  - Study the influence on bed behavior of different solid particles bed heights.
  - Comparison with numerical models.
  - Study variying the level of radiation.

- Research of new fluid-particle technologies.

- Develop numerical simulations with specific software.

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