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CFD simulations for a spouted bed reactor based pyrolysis pilot plant

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Ikerlan Technological Research Centre is developing a spouted bed reactor based pyrolysis pilot plant, to produce oil (2nd generation biofuel) and chemicals (fertilizers, active carbon, etc.) from biomass. The aim of the project is to gain knowledge on the spouted bed technology, in order to develop industrial scale plants.

CFD (Fluent v6.3) has been widely used during the design tasks. The analysis of different alternatives in the early stages has reduced the number of prototypes and experimental tests, which gives lower cost and developing time. CFD has been used in the design of the reactor (contactor with sand particles), the fluidizing gas preheater, and the cyclone separator.

Reactor

Geometry and materials

	Density, kg/m³	Voidage	Sauter diameter, mm	Shape factor
Silica sand	2600	0.36	1.05	0.75

Table 1. Particle properties

Diameter (mm)	242	Base diameter (mm)	52
Base cone angle (°)	32.2	Inlet diameter (mm)	15
Total height (mm)	1030		

Table 2. Reactor geometry

Figure 1. Spouted bed reactor.

CFD model

- 2D axisymmetric, 7900 cell hybrid mesh
- Euler-Euler approach
- Drag: Gidaspow (1992), C_D: Haider and Levenspiel (1989)
- Coefficient of restitution: 0.9
- Frictional viscosity: Schaeffer (1987)
- Boundary Conditions: air inlet velocity is increased linearly from 0 m/s to 65 m/s in 13 seconds. Then it is decreased down to 0 m/s at the same rate.
- UDF to include particle shape factor
- Ambient temperature

Results

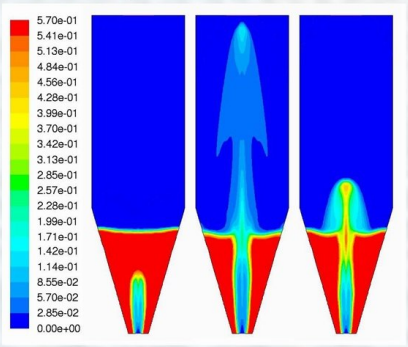
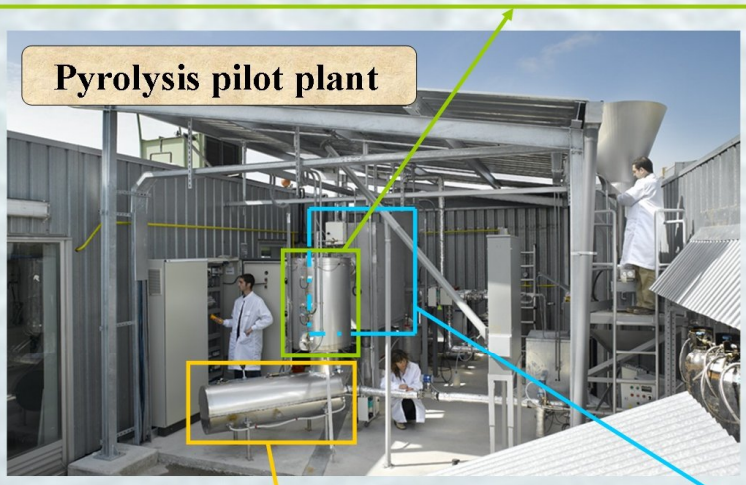


Figure 2. Volume fraction maps at different air inlet velocities, showing system's hysteresis: (left to right) u= 45 m/s (increasing vel.), u=65m/s, u=45 m/s (decreasing vel.).

Pyrolysis pilot plant



		Exp.	CFD
Spout formation	u_0 (m/s)	58	52
	ΔP (Pa)	1540	2380
Spout collapse	u_0 (m/s)	40	41
	ΔP (Pa)	1950	2740

Table 3. Comparison of experimental and simulated process control parameters.

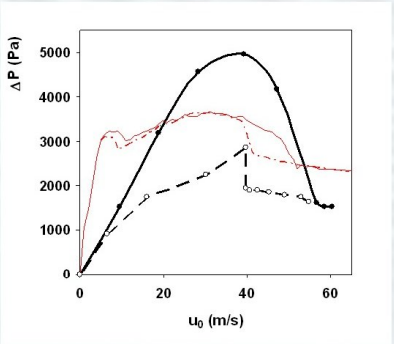


Figure 3. Experimental data (black) and calculated by CFD (red) for pressure drop evolution with inlet air velocity. Solid lines: increasing inlet air velocity. Dashed lines: decreasing inlet air velocity.

PID controlled gas preheater

Fluidizing gas preheater uses 2 independent electric heaters. Two-stage PID controller has been simulated, by means of user defined routines. This control strategy allows a fast heating while avoiding abrupt temperature changes and heat exchanger overheating.

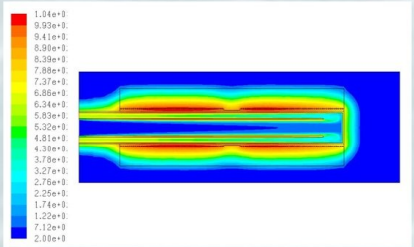


Figure 4. Temperature (C) contours at fluidizing gas preheater symmetry plane, 1 hour after start-up.

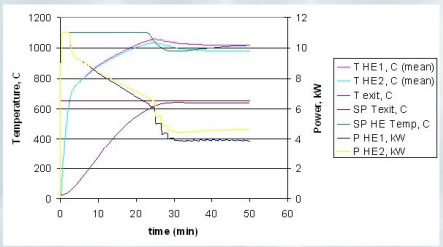


Figure 5. Instantaneous power consumption and mean temperature of Heating Elements, gas exit temperature, and control Set Points for gas exit temperature and heating elements.

Cyclone separator

Cyclone efficiency has been calculated for several char particle sizes. Simulations show that only particles under 10 microns and shape factor under 0.3 escape from the cyclone.

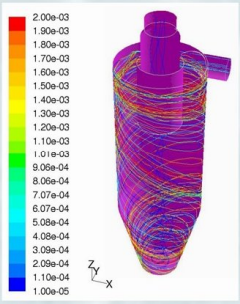


Figure 6. Particle tracks coloured by particle diameter.

Figure 7. Cyclone.

Conclusions and future work

- CFD is a useful tool for qualitatively determinate the minimum spouting velocity and pressure drop in conical spouted beds.
- Nevertheless, key issues need to be addressed in order to further improve CFD predictions, such as inclusion of granulometric distribution of sand and improvement of turbulence modelling.
- In future developments, fluidizing gas will be preheated by burning pyrolysis gaseous by-products. CFD is expected to play an important role in this task.

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