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A 1.5D model of a complex geometry laboratory scale fuidized bed clc equipment

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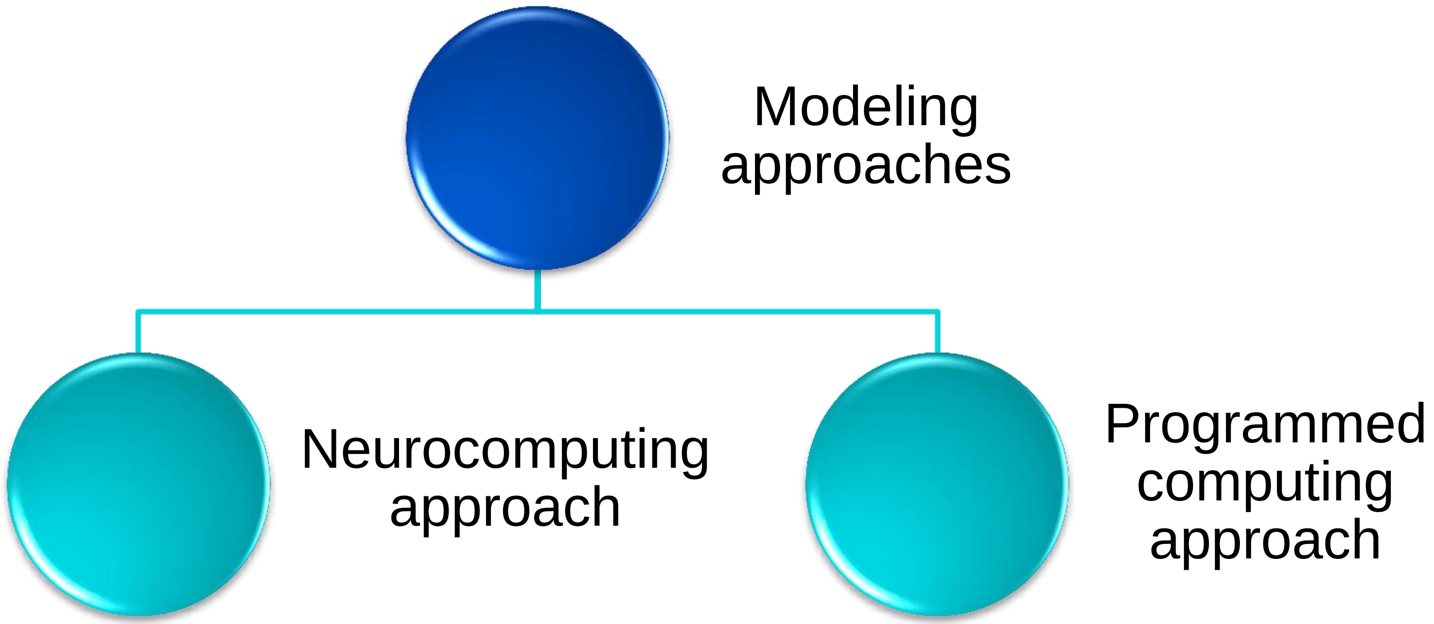
Fluidization XV
A ECI Conference Series

May 22-27, 2016
Fairmont Le Chateau Montebello
Quebec, Canada

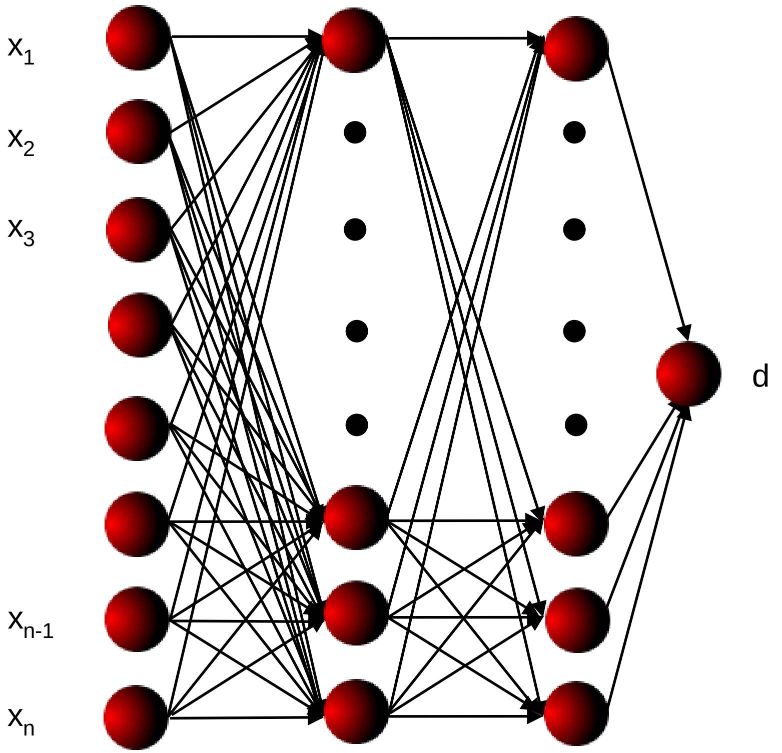
A 1.5D MODEL OF A COMPLEX GEOMETRY LABORATORY SCALE FUIDIZED BED CLC EQUIPMENT

J. Krzywanski, A. Zylka, T. Czakiert, K. Kulicki, S. Jankowska, W. Nowak,

Different Modeling Approaches



THE NEUROCOMPUTING APPROACH



- Krzywanski J., Czakiert T., Blaszczuk A., Rajczyk R., Muskala W., Nowak W., A generalized model of SO2 emissions from large- and small-scale CFB boilers by artificial neural network approach Part 2. SO2 emissions from large- and pilot-scale CFB boilers in O2/N2, O2/CO2 and O2/RFG combustion atmospheres, Fuel Processing Technology 139 (2015) 73–85.
- Krzywanski J., Nowak W., Artificial intelligence treatment of SO_2 emissions from CFBC in air and oxygen-enriched conditions, , J. Energy Eng. 142 (2015) Issue 1, Article Number 04015017

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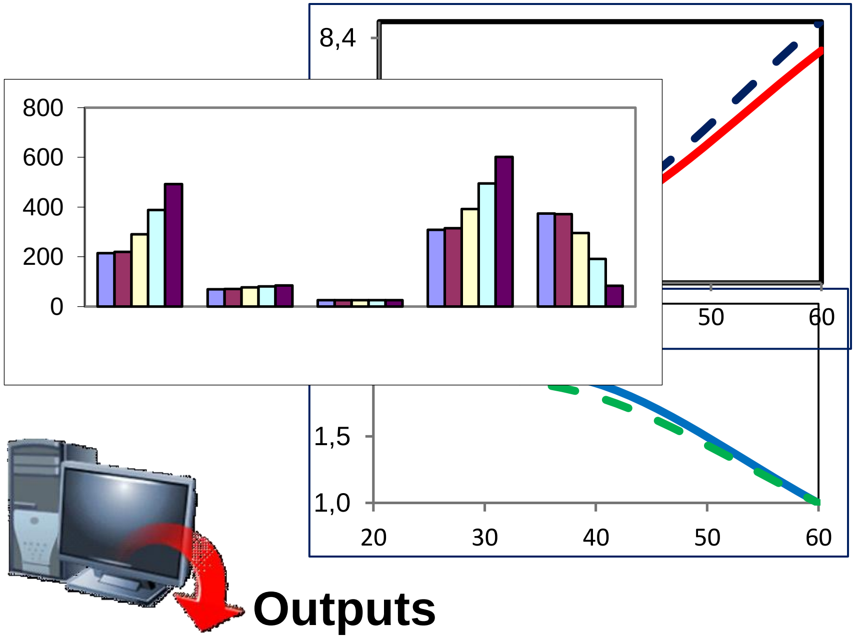
The Programmed Computing Approach

Inputs

- **Geometry**
- **Solid and fluid properties (coal, O_2/CO_2 gas mixture)**
- **Operational conditions**

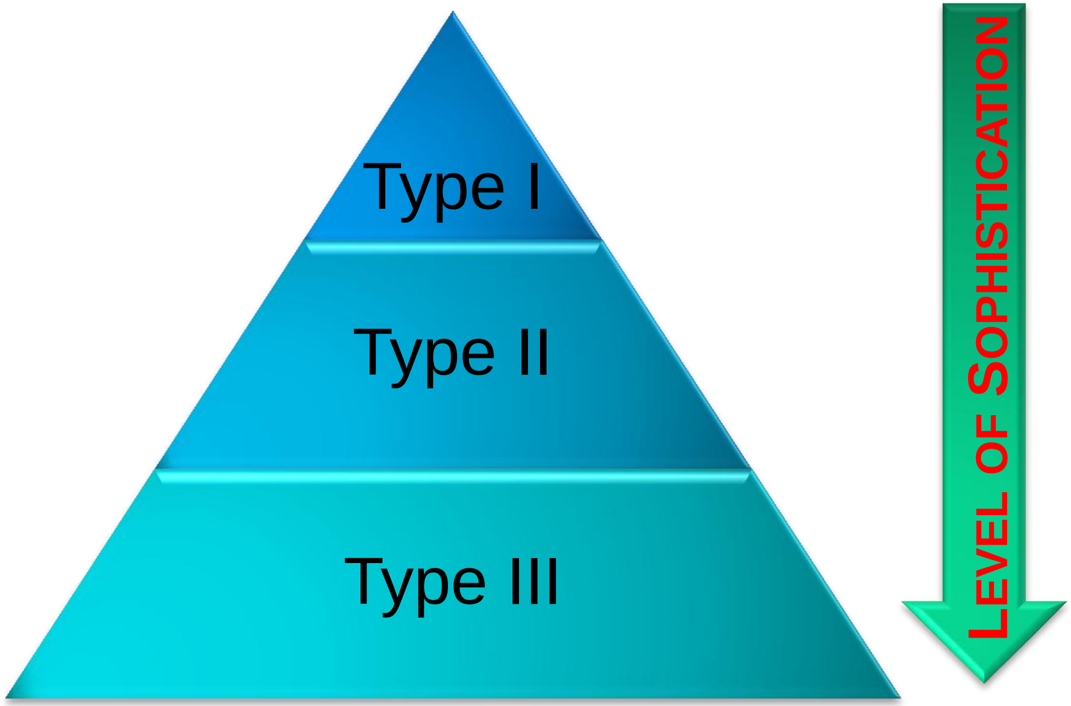


Outputs

Solid profile
Mass flux
Temperature profile
Heat flux

- **Numerical procedures**
- **Validation**

The Programmed Computing Approach



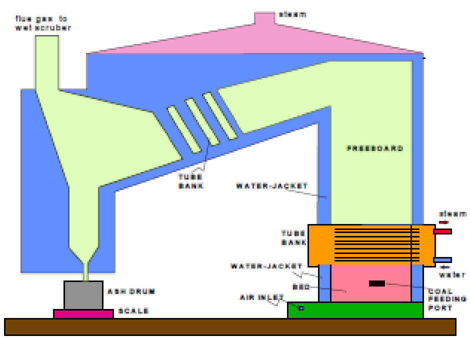
Krzywanski J., Czakiert T., Blaszczuk A., Rajczyk R., Muskala W., Nowak W., (2015) A generalized model of SO2 emissions from large- and small-scale CFB boilers by artificial neural network approach, Part 1. The mathematical model of SO2 emissions in air-firing, oxygen-enriched and oxycombustion CFB conditions, Fuel Process Technol 137, 66 – 74

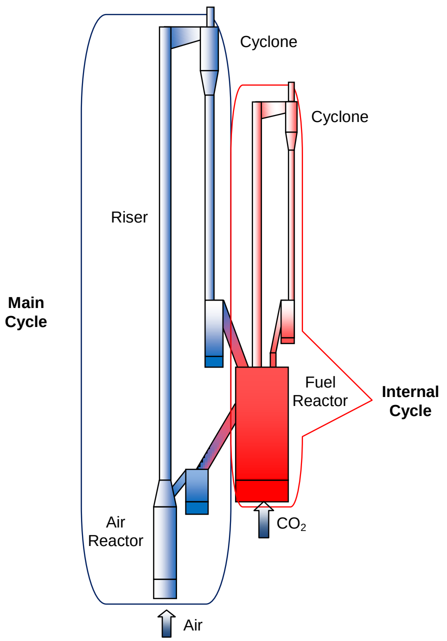
The 1.5D Model

CeSFaMB™/CSFMB©

Comprehensive Simulator of Fluidized and Moving Bed Equipment

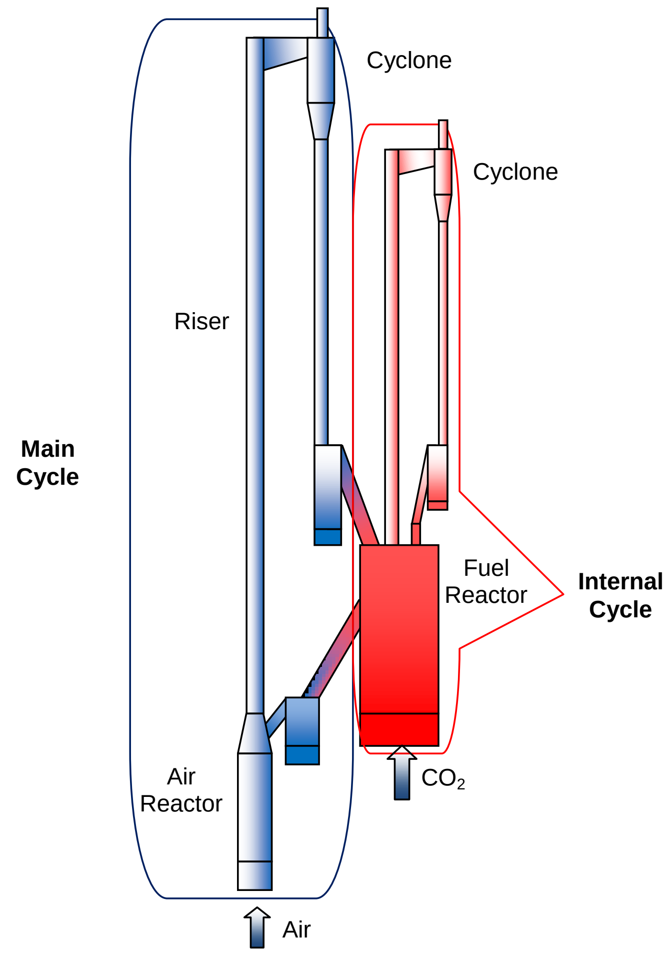
Series 64





The FB-CLC-SF unit

The FB-CLC-SF facility



GEOMETRY

The main dimensions of the CLC unit [m]

The diameter of the air reactor	0.102
The diameter of the riser	0.044
The total height of the AR and riser	2.5
The hydraulic diameter of chambers I and II of the FR	0.0714
The total height of the FR	0.5

MATERIALS

The main properties of the solids (round glass microspheres)

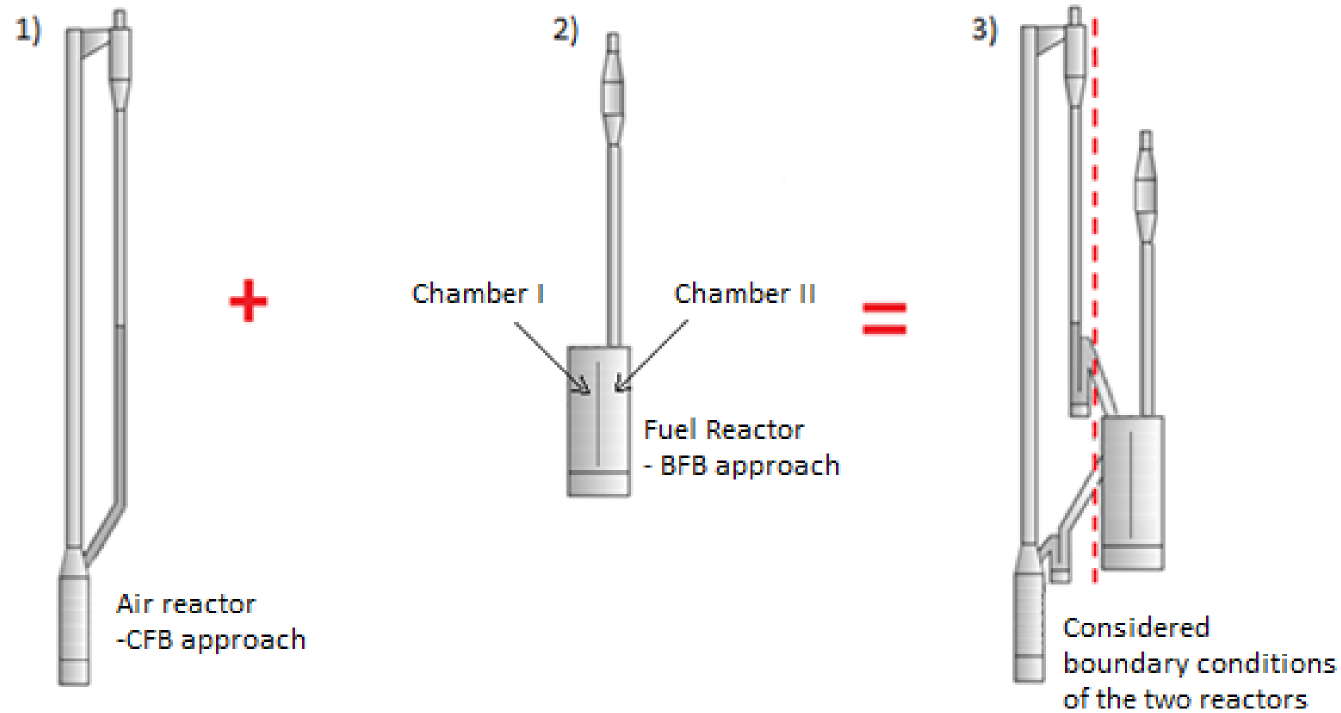
The Sauter mean diameter of particles	141 μm
Density	2450 kg m^{-1}
Sphericiy	0.9

CALCULATION CONDITIONS

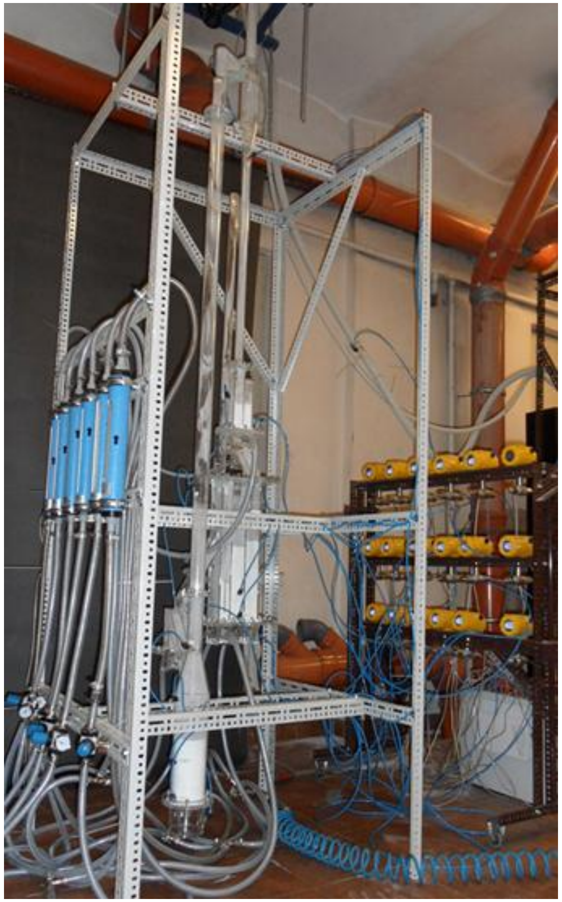
Main operational conditions of the FB-CLC-SF unit

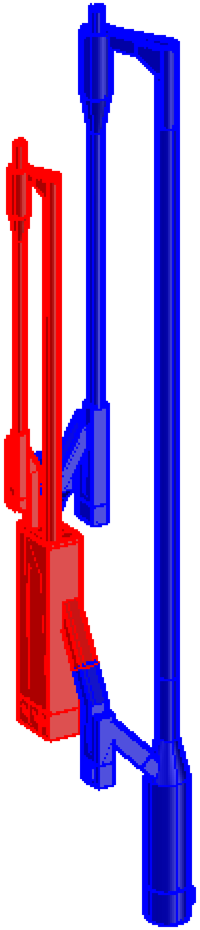
No of test	**1**	**2**	**3**
Gas flux in AR, [$^x3600^{-1}$ m^3 s^{-1}]	11.00	14.50	18.10
Gas flux in FR, [$^x3600^{-1}$ m^3 s^{-1}]	9.50	9.50	9.50
Temperature, [K]	293.15	293.15	293.15
Absolute pressure below the gas distributor in AR, [Pa]	104 614	104 450	104 480
Absolute pressure below the gas distributor in FR, [Pa]	104 137	104 303	104 372
Total mass of solids in the AR [kg]	2.28	1.88	1.57
Total mass of solids in the FR [kg]	2.17	2.33	2.40

Modeling Approach



VALIDATION





The FB-CLC-SF facility

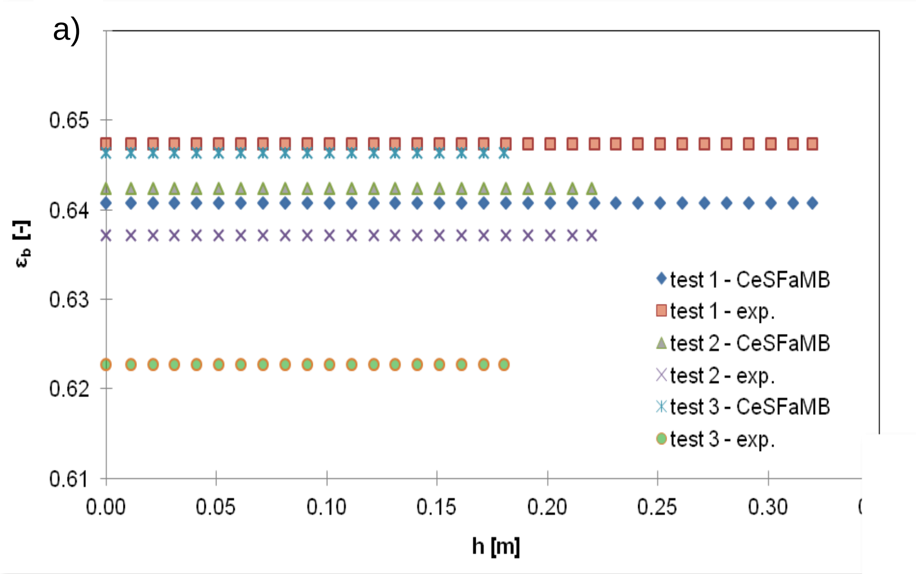
RESULTS

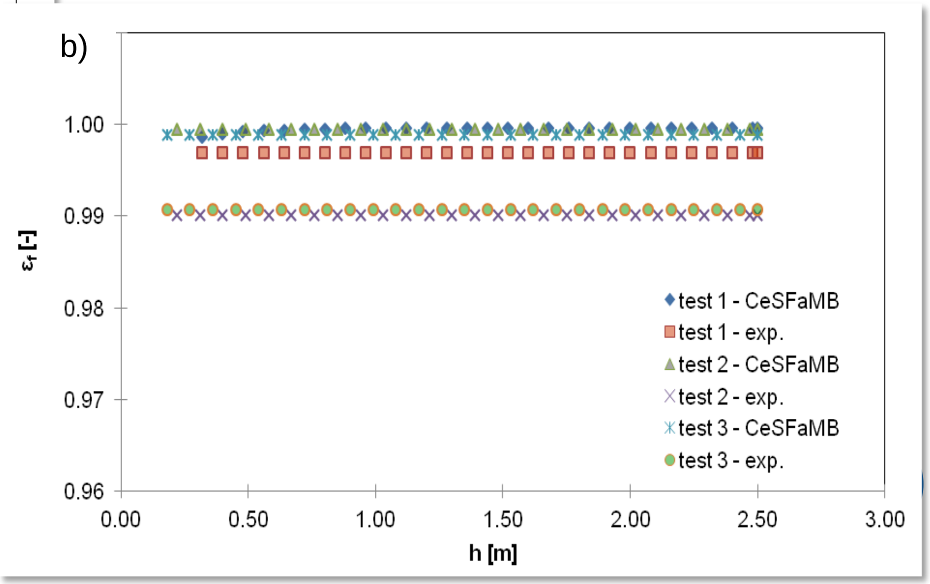
Hydrodynamics

MAIN PRESSURE LOSSES

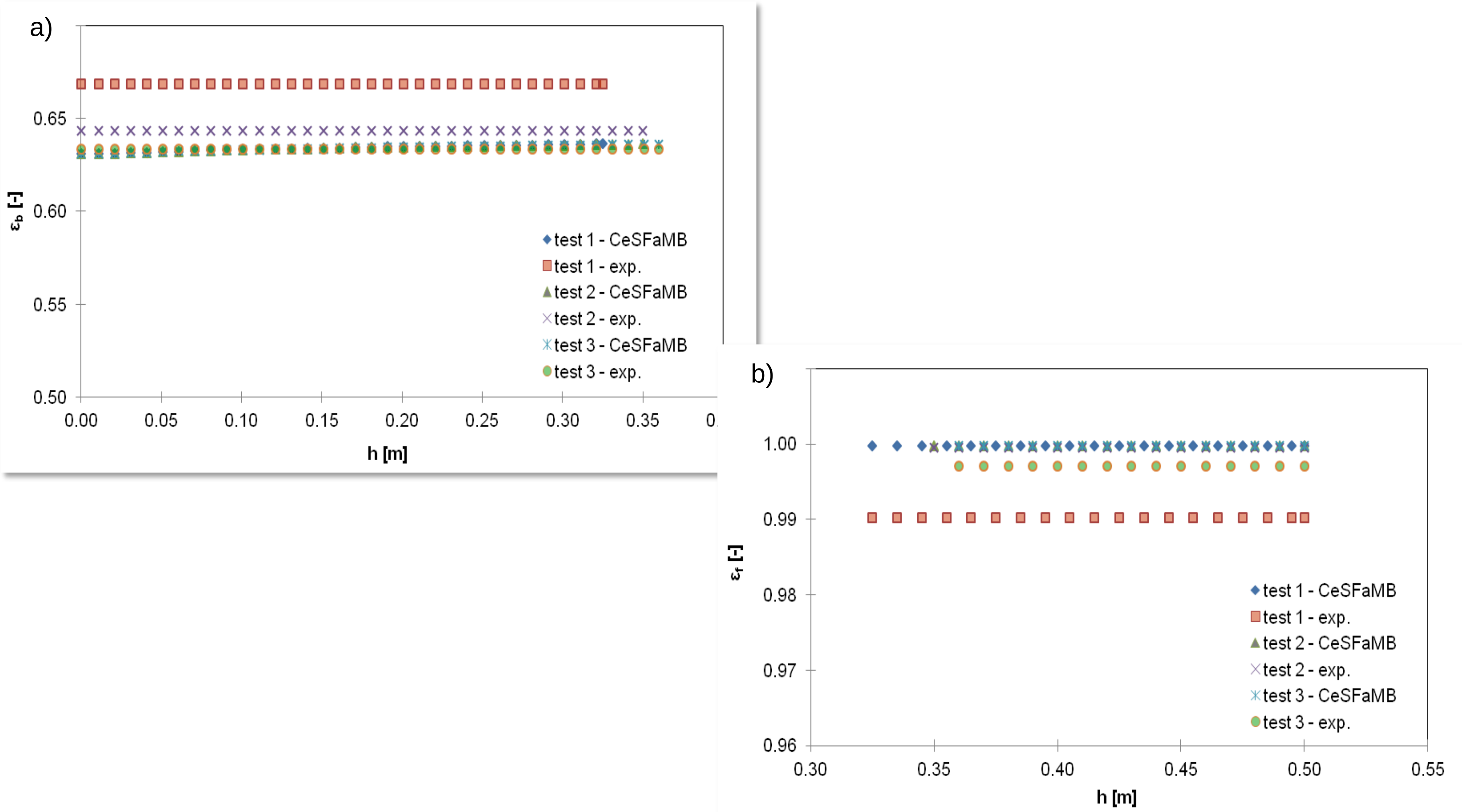
No of test	1	Err [%]	2	Err [%]	3
Air Reactor	2 712	2.12	1 918	0.95	1 632
Fuel Reactor	2 238	3.22	2 392	3.66	2 448

Void Fractions in AR & Riser

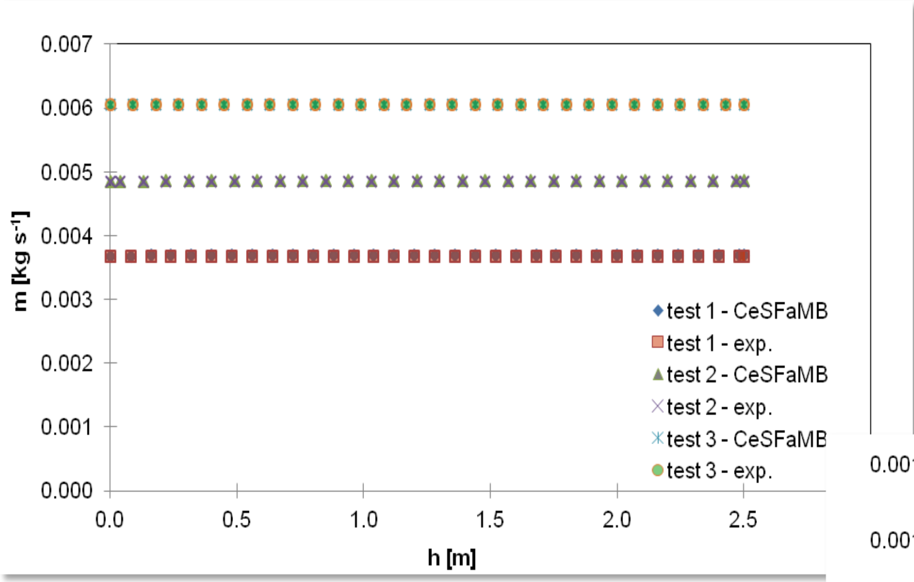


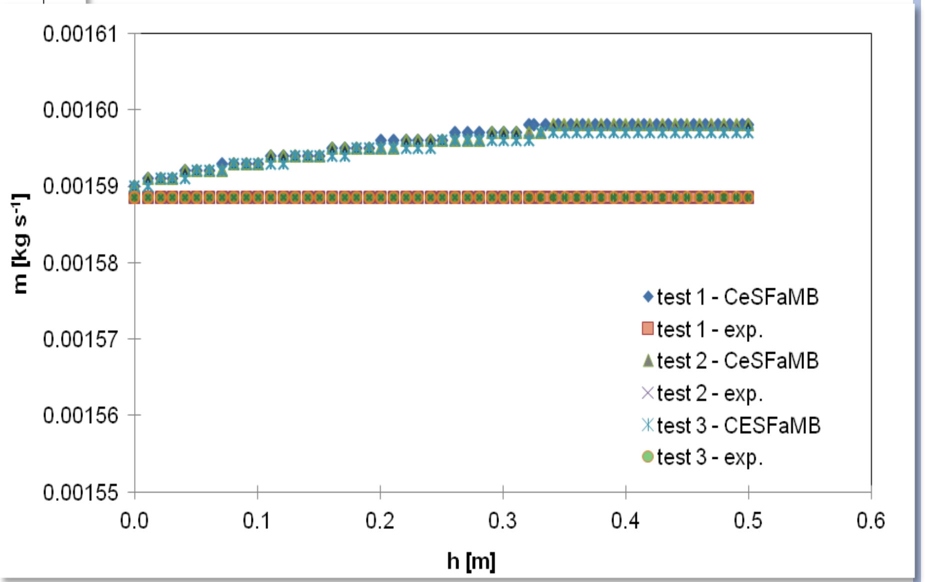


VOID FRACTIONS IN FR



GAS MASS FLOW RATE IN AR & FR



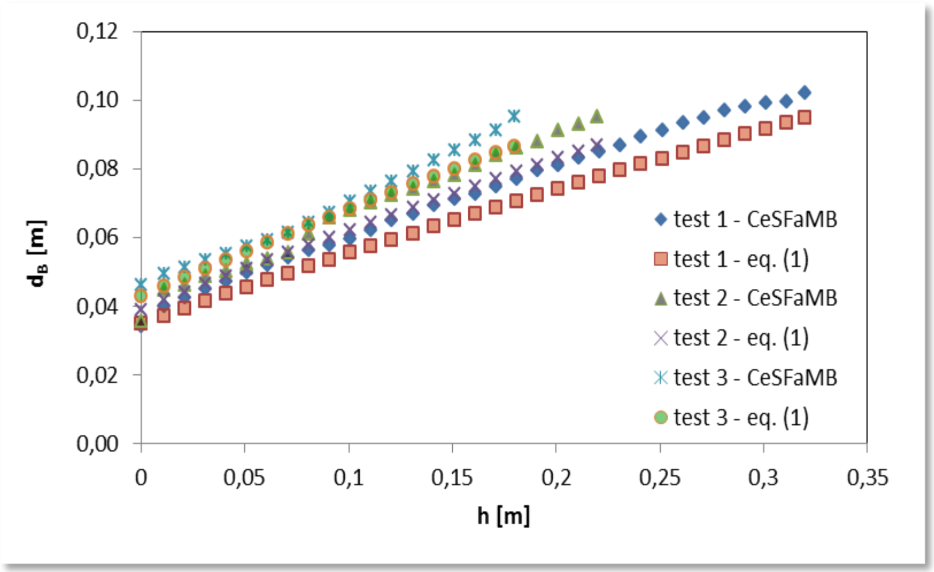


BUBBLE DIAMETER & RISING VELOCITY

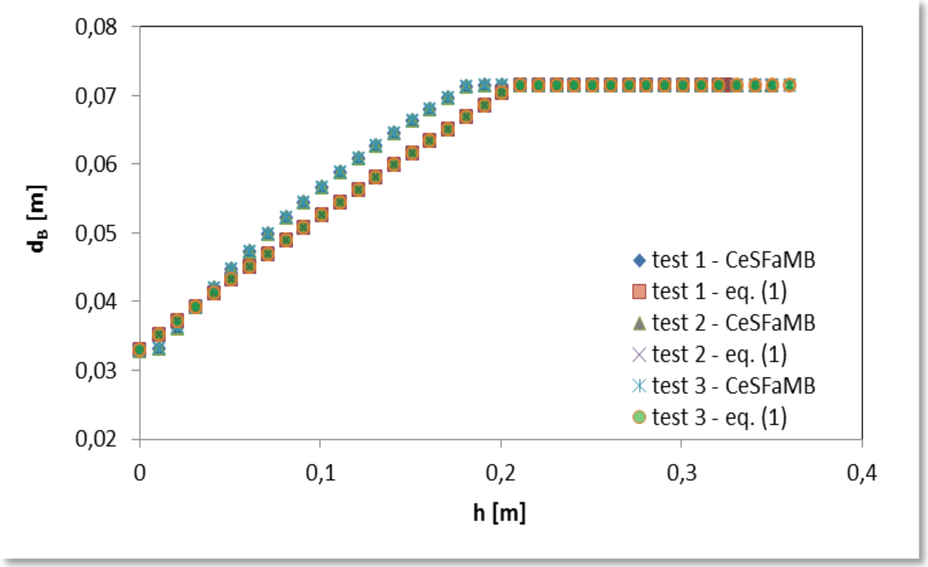
Correlation	No of equation
$d_B = 0.43\left(U - U_{mf}\right)^{0.4}(h + 0.1272)^{0.8} g^{-0.2}$	(1)
$U_B = U - U_{mf} + 0.711\left(g\, d_B\right)^{0.5}$	(2)

- Marcio L.de Souza-Santos: Solid Fuels Combustion and Gasification. Modeling, Simulation, and Equipment Operation, 2005.
- Marcio L.de Souza-Santos: Second edition Solid Fuels Combustion and Gasification. Modeling, Simulation, and Equipment Operation, 2010.

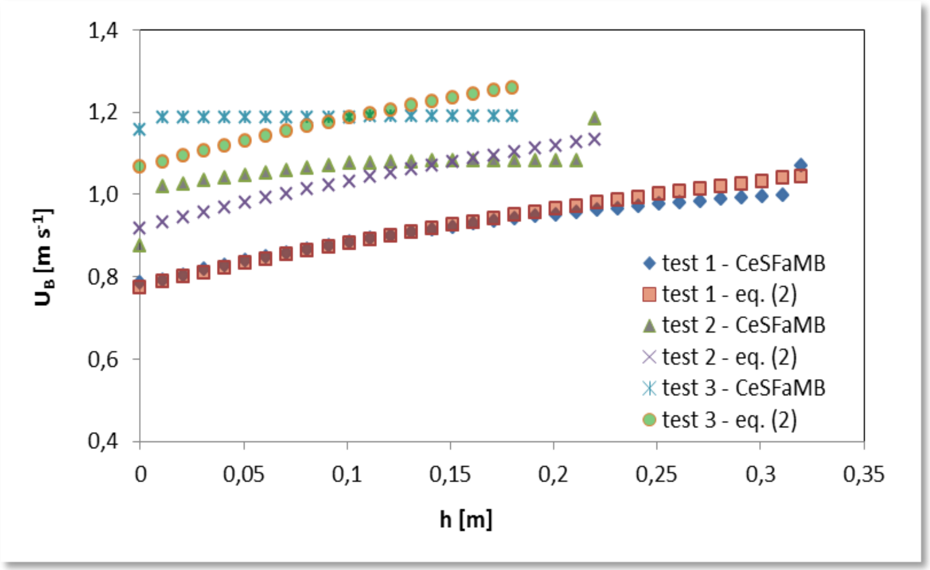
BUBBLE DIAMETER IN AR



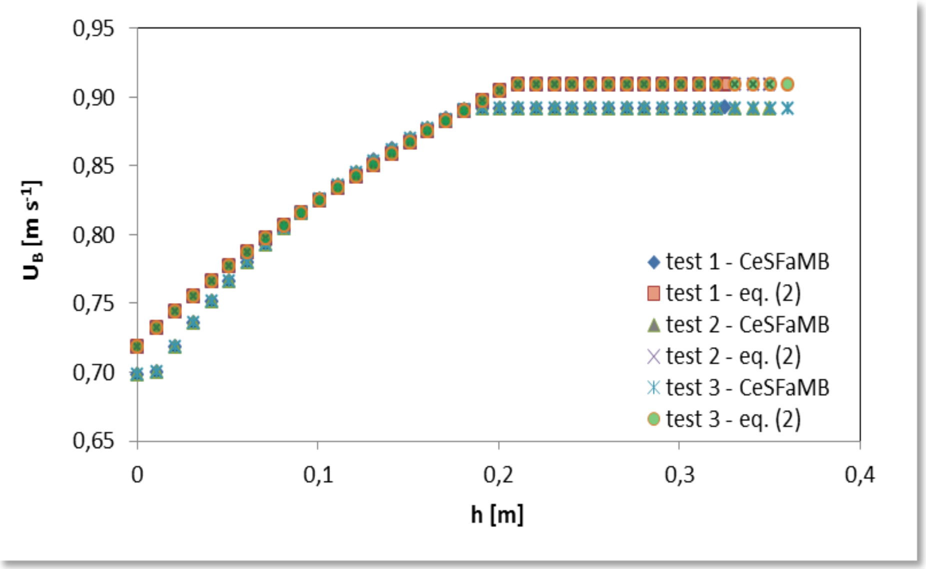
BUBBLE DIAMETER IN FR



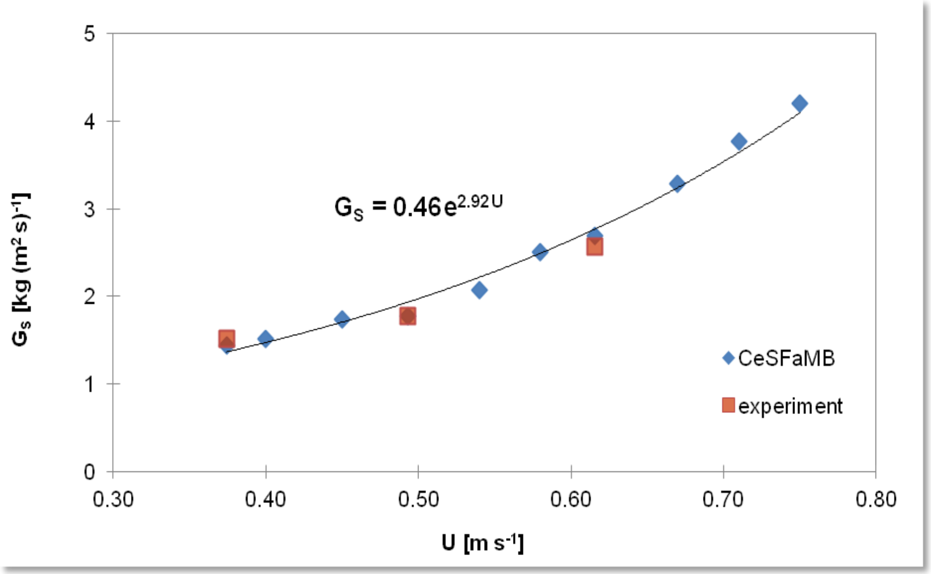
RISING VELOCITY IN AR



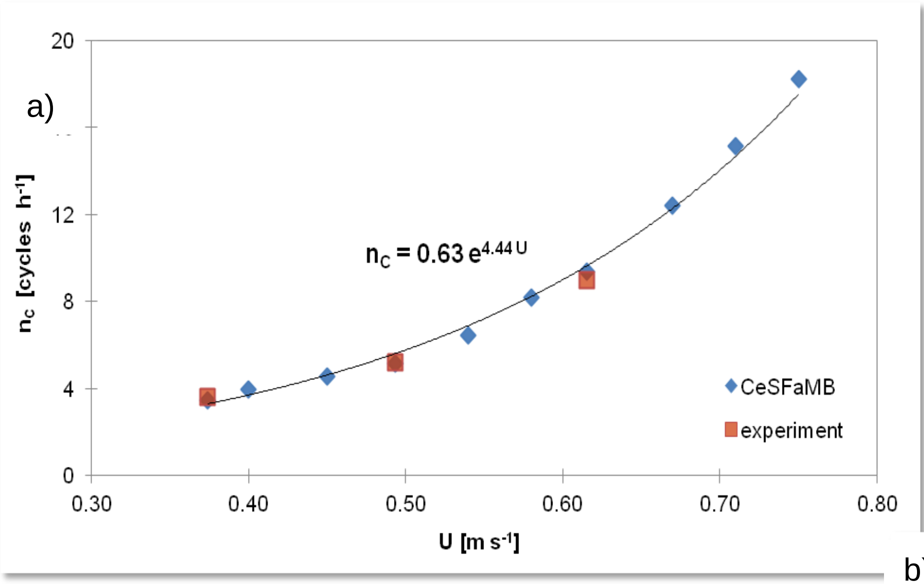
RISING VELOCITY IN FR

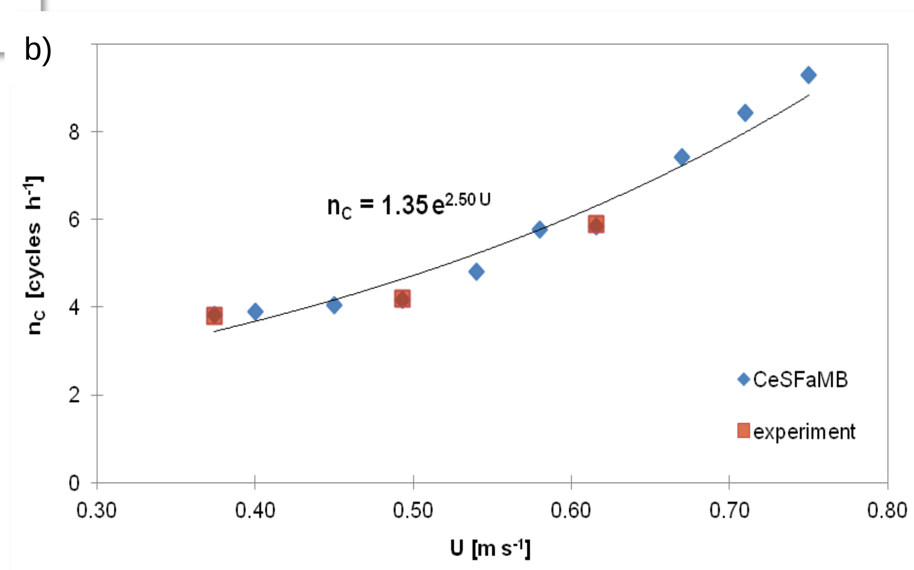


Solids circulating rate in AR

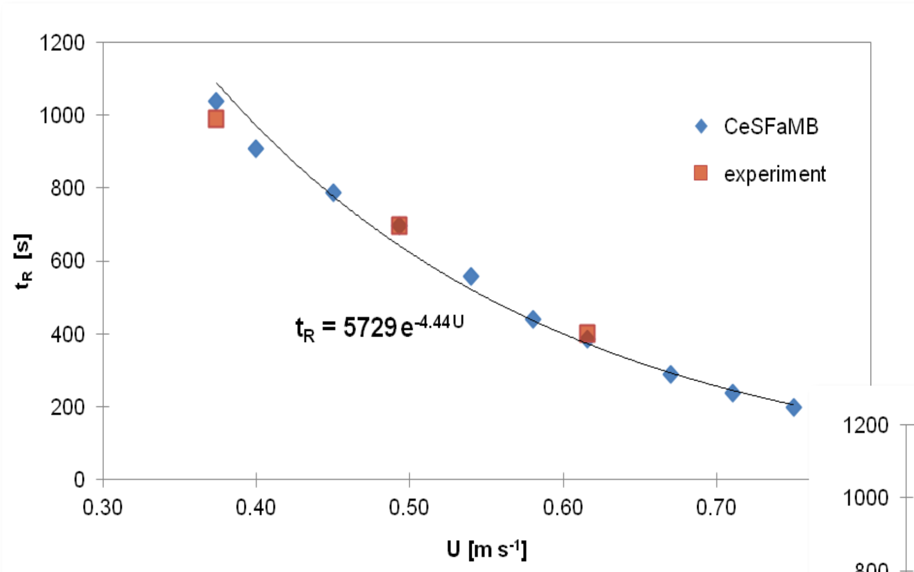


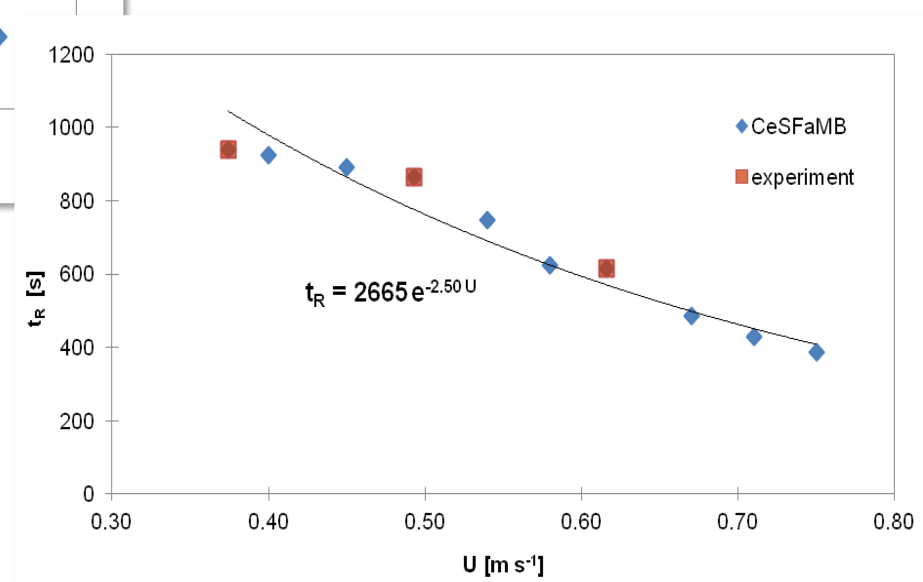
NUMBER OF CYCLES



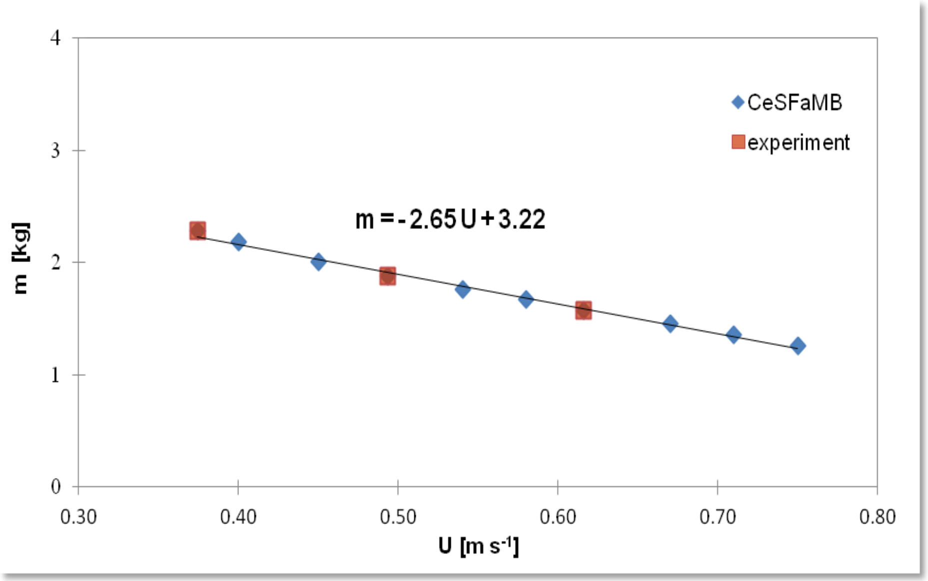


PARTICLES' RESIDENCE TIME

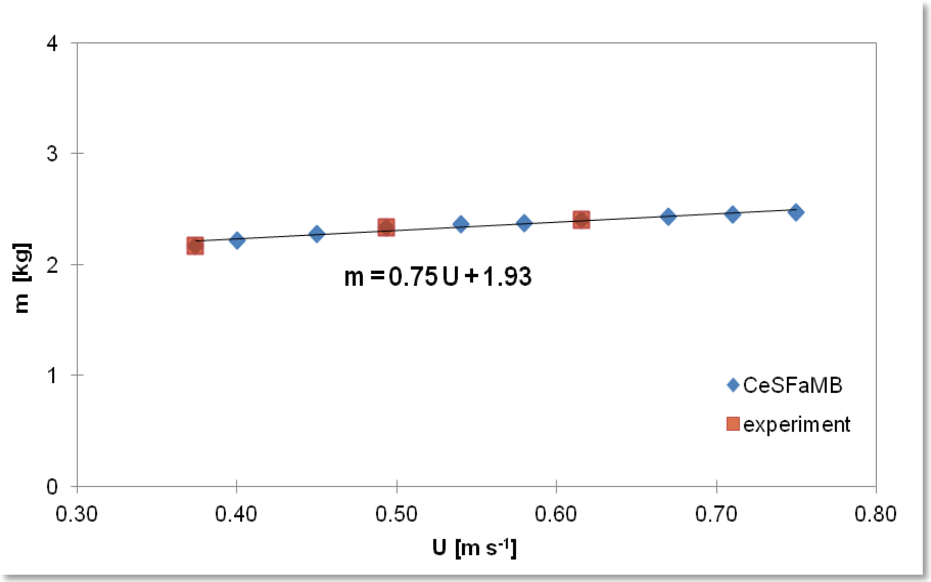




Total mass of solids in AR



Total mass of solids in FR



CONCLUSIONS

The simulations are carried out by 1.5D completed by the use of CeSFaMB Simulator.

The maximum relative error between measured and calculated data does not exceed 10 %.

Simulations showed, that the performed 1.5D model correctly describes the fluidization dynamics and can be applied to study the fluidized bed CLC unit operation.

The described investigations are to be a reference point for further simulations of 5-7 kW_{th} hot CLC test rig.

ACKNOWLEDGMENTS

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