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CFD modelling of reactors for reducing the environmental impact of SO_2 emissions

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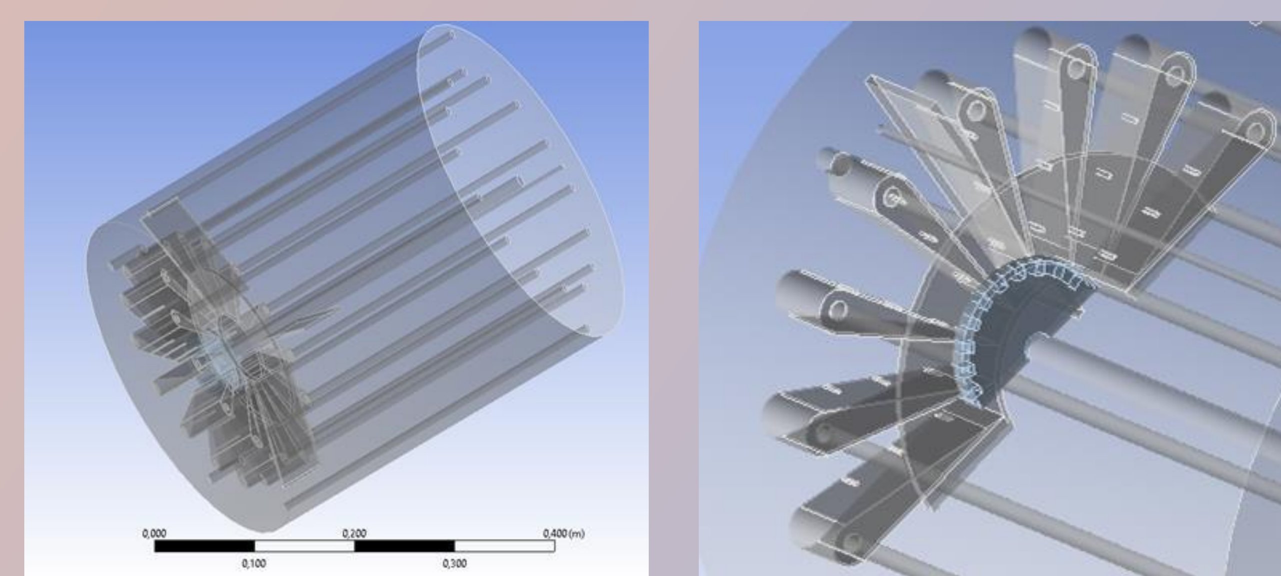
Bubble reactor with a slot gas disperser

EXPERIMENTAL

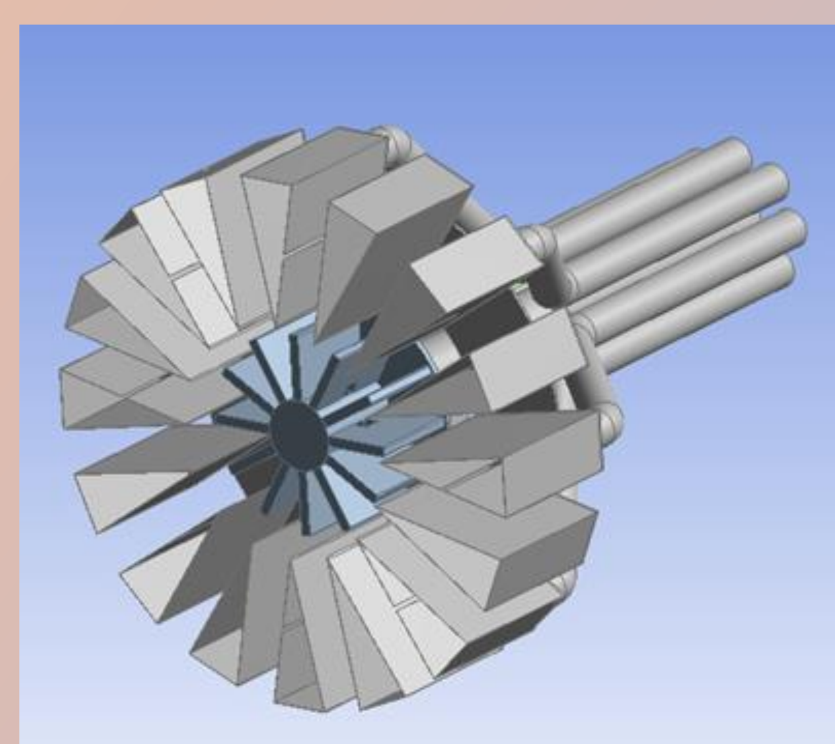
Reactor volume, m^3	0.04	1.5
Diameter D, m	0.35	1.206
Height H, m	0.46	1.00-1.115
Type of stirrer	WP	WD
Diameter of impeller	0.07	0.400
Width of slot, mm	2	10
Height of slot, mm	30	185
Rotor speed, $m\cdot s^{-1}$	7	7
Flow rate of inlet gas V_g, $m_N^3\cdot h^{-1}$	5.3	150-750
SO_2 concentation		
inlet gas, vol. %	5.2-8.5	1.5-7.4
outlet gas, ppm	8-79	43-289
Temperature, °C	63-73	50-65
Slurry density, $g\cdot dm^{-3}$	223-285	254-399

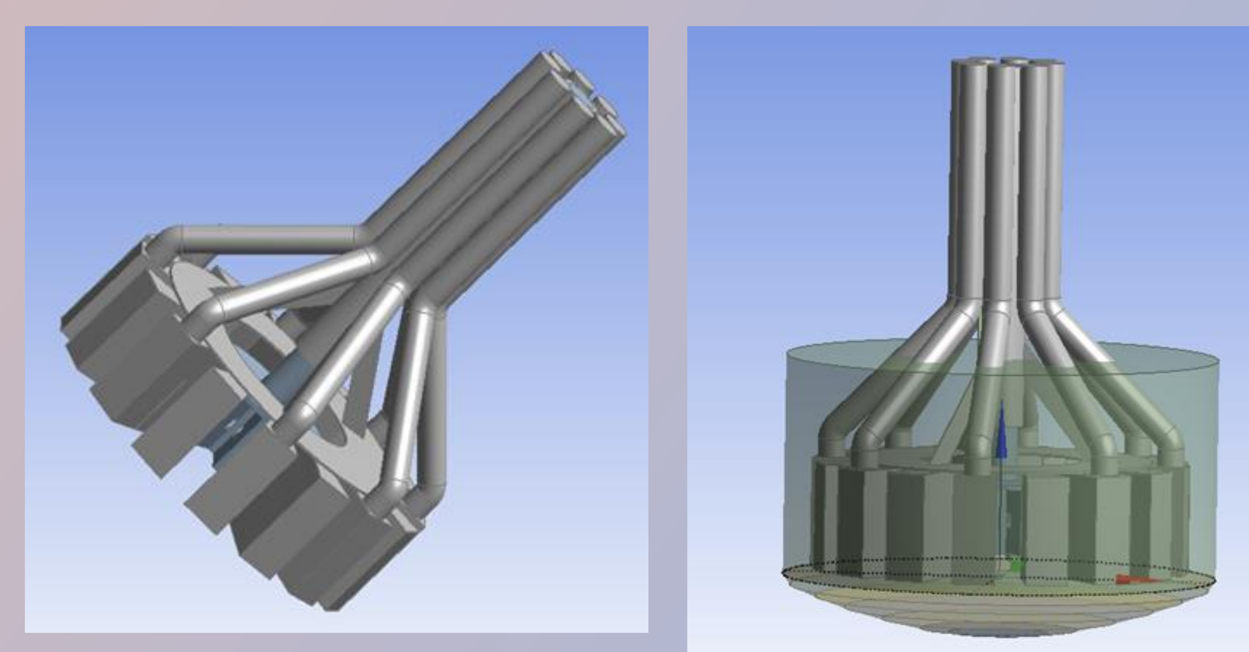
Experimental studies conducted in a 40 dm^3 and 1.5 m^3 bubble reactor with a slot gas disperser confirmed usefulness of developed technology for deep desulfurization of SO_2-rich gases with production of coarse-crystalline gypsum.

CFD model of geometry



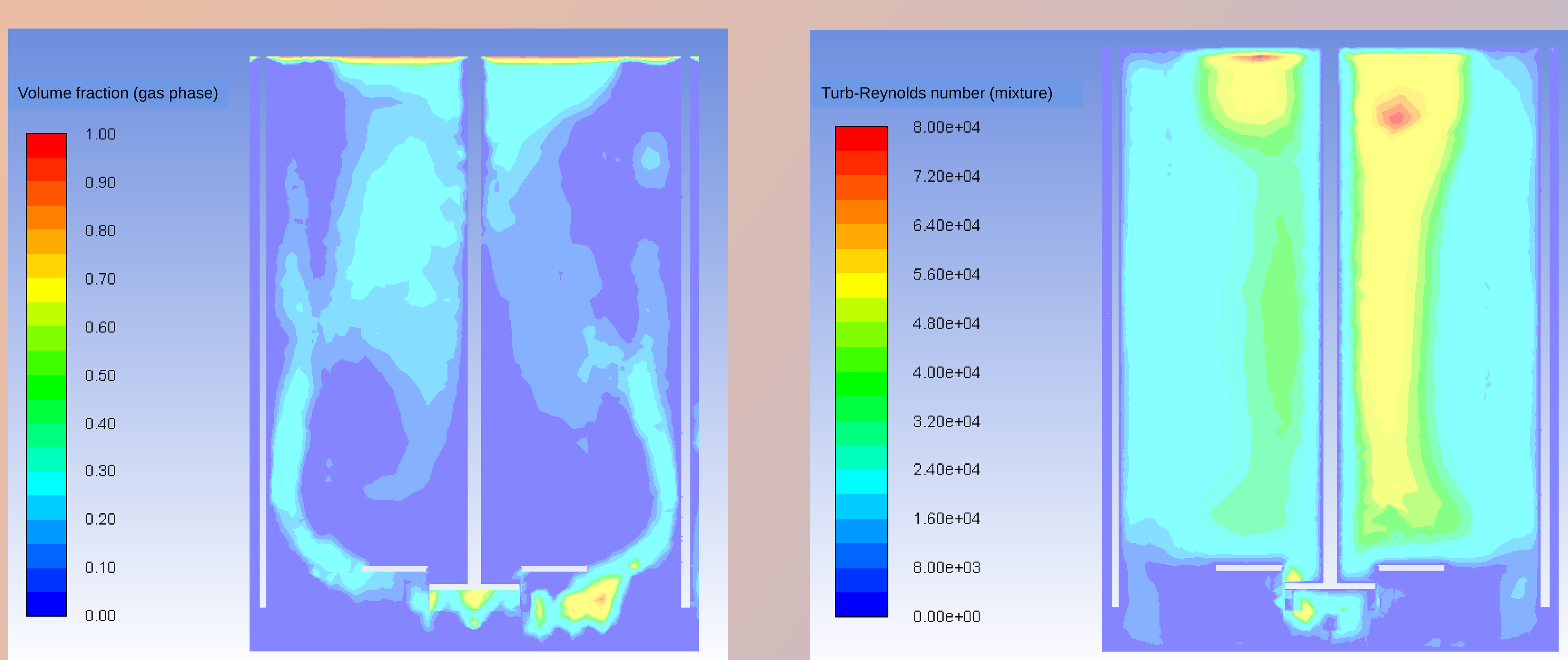
Geometry of the bubble reactor of 0.04 m³



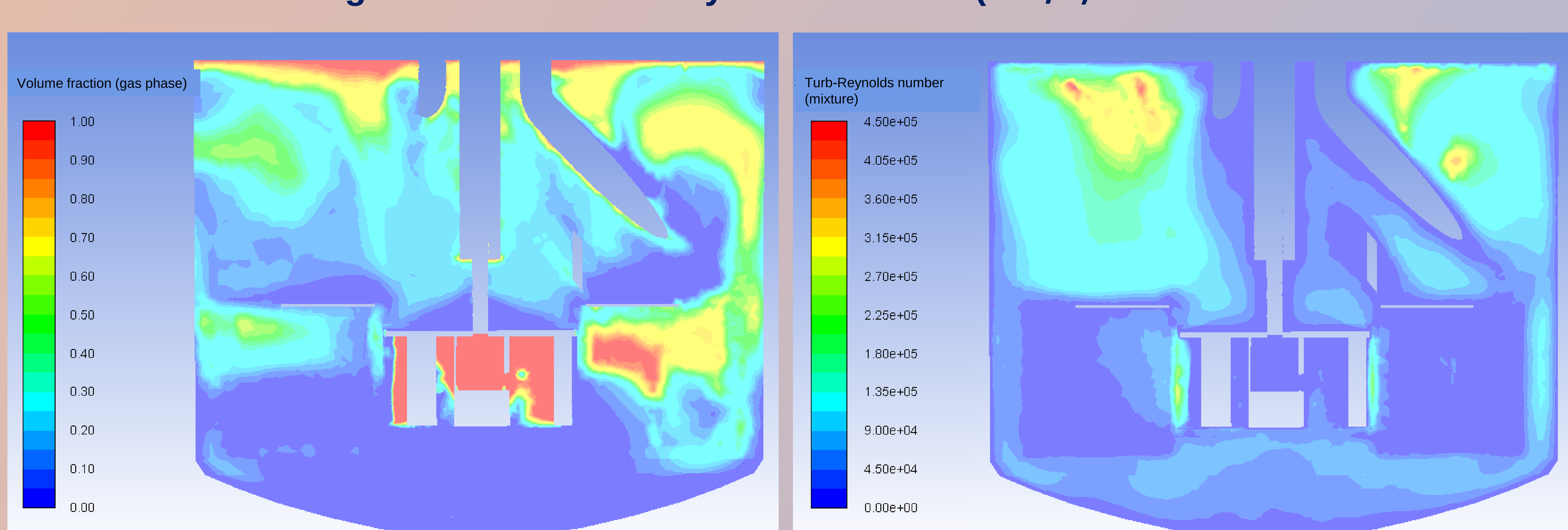


Geometry of the bubble reactor of 1.5 m³ working capacity

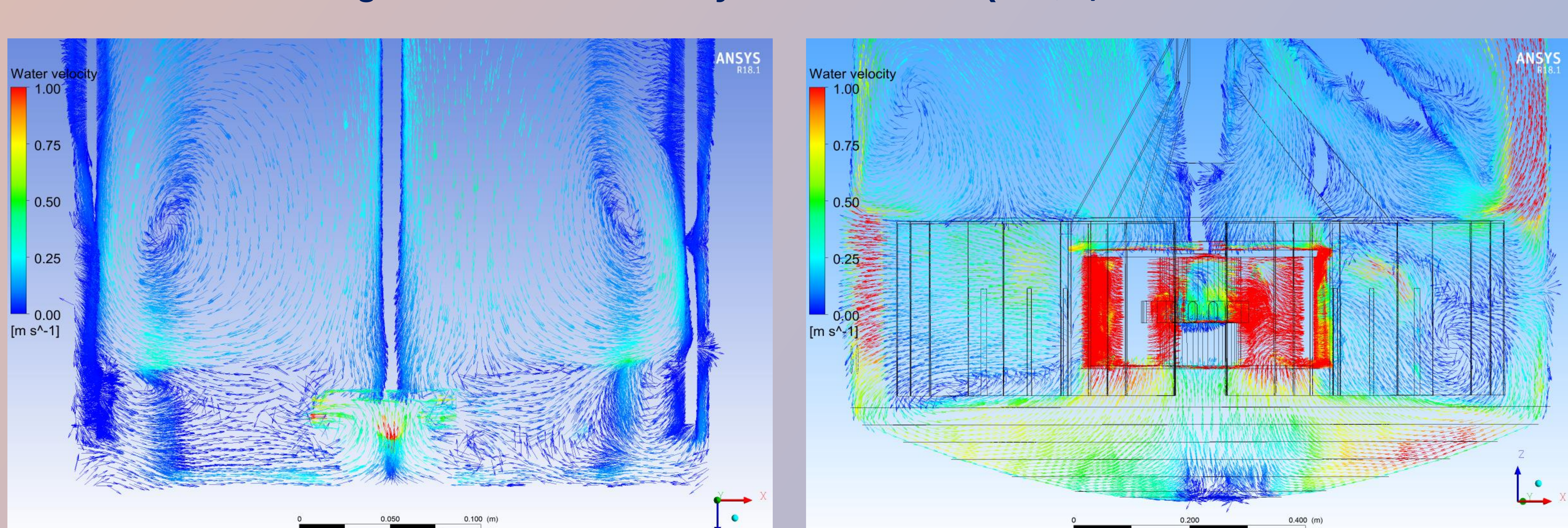
CFD MODELLING OF HYDRODYNAMICS IN A BUBBLE REACTOR



Volume fraction of gas and turbulent Reynolds number ($k^2\cdot\varepsilon/\nu$) in a 0.04 m³ bubble reactor



Volume fraction of gas and turbulent Reynolds number ($k^2\cdot\varepsilon/\nu$) in a 1.5 m³ bubble reactor



Water velocity vectors on the plane fitting to the disperser blade in a 0.04 m³ (left) and 1.5 m³ (right) reactor

- Commercial program Fluent R18.1 from ANSYS
- Eulerian model extended to three phases - equations of conservation of mass and momentum are solved separately for each phase present in the system

$$\frac{\partial}{\partial t}(\alpha_k\rho_k)+\nabla(\alpha_k\rho_k\vec{u}_k)=0 \qquad k=g,l,s$$

$$\frac{\partial}{\partial t}(\alpha_k\rho_k\vec{u}_k)+\nabla(\alpha_k\rho_k\vec{u}_k\vec{u}_k)=-\alpha_k\nabla p+\nabla\cdot\bar{\bar{\tau}}_k+\alpha_k\rho_k\vec{g}+\vec{K}_k+\vec{F}_k$$

- Standard k-ε model of turbulence

$$\frac{\partial}{\partial t}(\rho_m k)+\nabla(\rho_m\vec{u}_m k)=\nabla\left(\left(\mu_m+\frac{\mu_{t,m}}{\sigma_k}\right)\nabla k\right)+G_{k,m}-\rho_m\varepsilon$$

$$\frac{\partial}{\partial t}(\rho_m\varepsilon)+\nabla(\rho_m\vec{u}_m\varepsilon)=\nabla\left(\left(\mu_m+\frac{\mu_{t,m}}{\sigma_\varepsilon}\right)\nabla\varepsilon\right)+\frac{\varepsilon}{k}\left(C_{1\varepsilon}G_{k,m}-C_{2\varepsilon}\rho_m\varepsilon\right)$$

- The MRF model for rotational movement of the stirrer
- Steady-state formulation
- Gas bubble diameter – $1\cdot10^{-3}$ m
- Gypsum particle diameter - $35\cdot10^{-6}$ m
- Power of mixing:

$$P_{turb}=\int\varepsilon\,dm \qquad P_{imp}=2\pi N M_{imp}$$

Experimental and calculated values of parameters in 1.5 m³ reactor

Flow rate of inlet gas, $m_N^3\cdot h^{-1}$	Direction of stirrer rotation	Pressure of inlet gas, kPa		Mixing power, kW		
		Exp.	Calc.	Exp.	P_{turb}	P_{imp}
175.52	„-”	6.6	6.64	5.56	5.61	5.17
293.28	„-”	6.9	6.88	5.21	5.41	4.88
175.52	„+”	5.2	5.20	5.43	5.87	5.34
293.28	„+”	5.4	5.40	5.13	5.64	5.14

The result analysis confirmed the principal qualitative and quantitative conclusions resulting from the relevant experimental desulfurization studies.

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