Pulse dynamic visualization in foam packed reactors – flow path evolution

J. Zalucky[1], S.S. Rabha[1], M. Schubert[1], U. Hampel[1,2]

[1] Helmholtz-Zentrum Dresden-Rossendorf, Germany, [2] Technische Universität Dresden, Germany

INTRODUCTION

- Pulse flow is well-known for its performance enhancing effects in co-current downflow due to continuous re-wetting and liquid flow intensified shear stress [1].
- The contribution investigates pulse flow hydrodynamics system in solid foams made of SiSiC (silicon infiltrated silicon-carbide) as novel catalyst support with high porosity and specific surface area.

METHODOLOGY

- Investigation of strongly transient pulse flows in two cross-sections by ultra-fast dual-plane X-ray computed tomography system [2]

Table 1: Investigation parameters

Parameter	Value	
Plane sampling frequency	1000	fps
Average spatial resolution	0.001	m
Reactor diameter	0.1	m
Reactor length	0.8	m
Nominal pore density	20; 45	ppi
Packing porosity	0.92; 0.88	m³/m³

- Phase-discretization by referencing to dry attenuation image

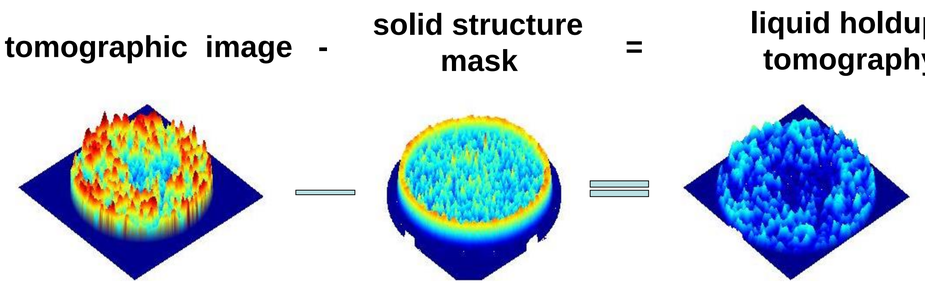


Fig. 1: Scheme of liquid holdup determination in the gas-liquid-solid system.

TIME-AVERAGE RESULTS

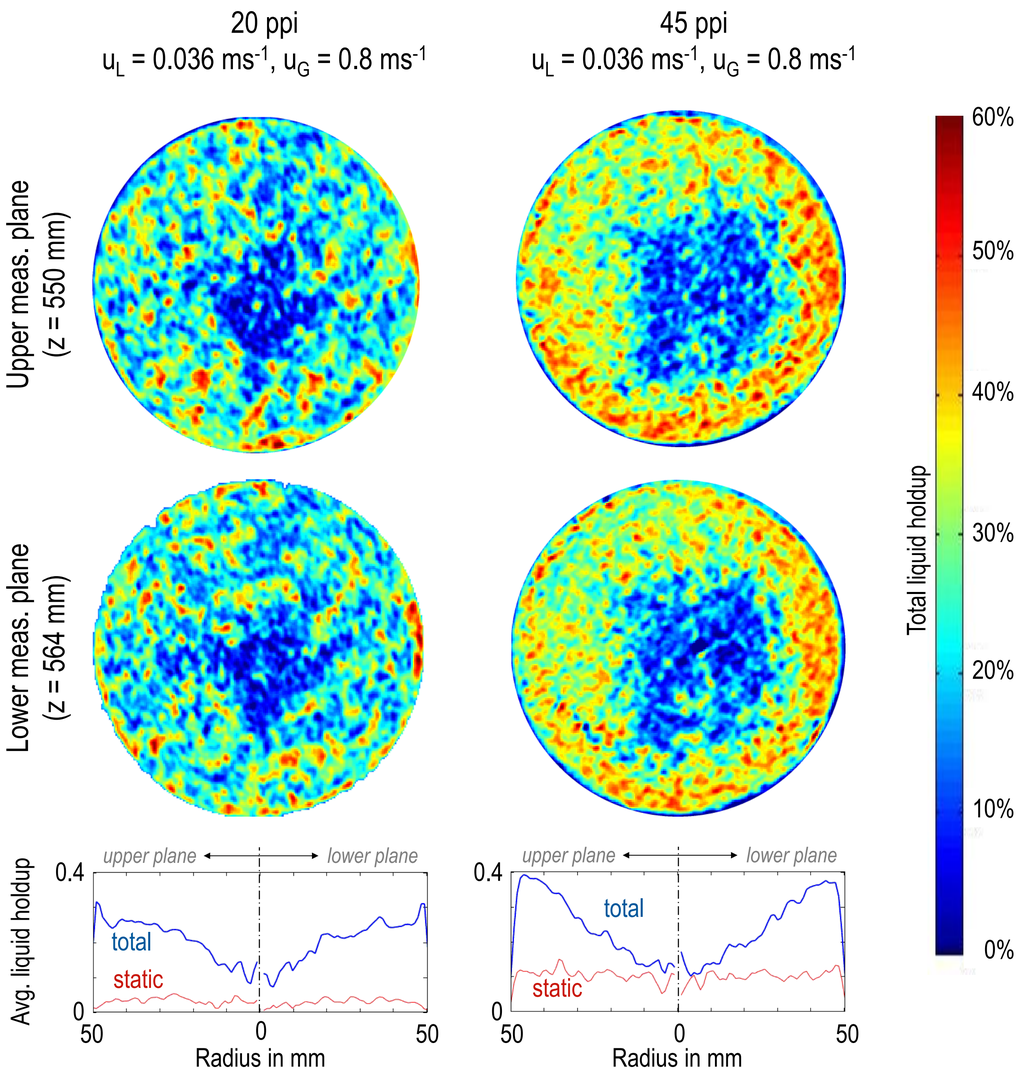
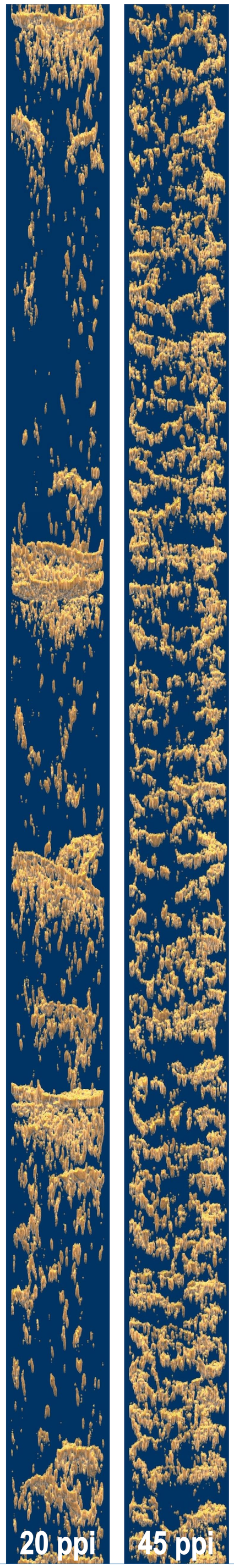


Fig. 2: Time-averaged liquid holdup values measure in 20 ppi (left) anf 45 ppi SiSiC solid foam under pulse flow conditions.

(1) → Low holdup core region due to imperfect initial cone spray nozzle distribution

(2) → Inhomogeneous wetting in outer ring region due to inhomogeneous structure

(3) → By-passing liquid at column wall



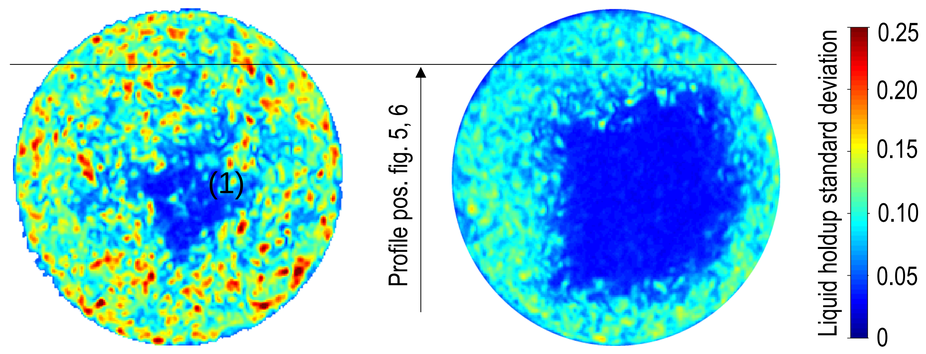


Fig. 4: Local standard deviation of liquid holdup values. Left: Lower plane in 20 ppi foam. Right: Upper plane in 45 ppi foam.

(1) → Though penetrated by pulses low holdup core remains

(2) → Pulse induced holdup fluctations in 20 ppi foam stronger than in 45 ppi foarm

(3) → Pulses in 45 ppi foam show ring shape of initial maldistribution

TIME-RESOLVED RESULTS

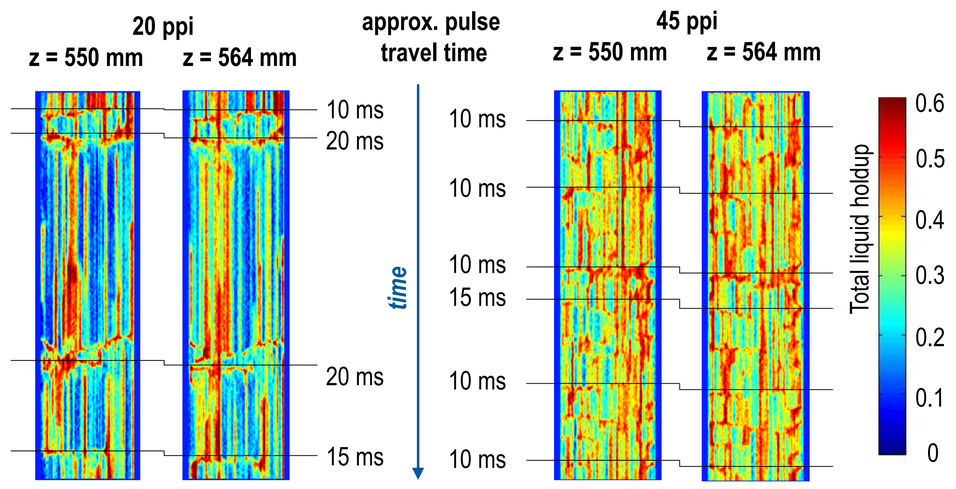


Fig. 5: Temporal evolution of liquid holdup profile over 1000 milliseconds in 20 ppi and 45 ppi solid foams at positions marked in fig. 4.

(1) → Pulse travel times in range of 10 to 20 ms, corresponding to average velocities of 1.4 to 2.8 ms^{-1}

(2) → Pulsing more frequent in the finer 45 ppi solid foam

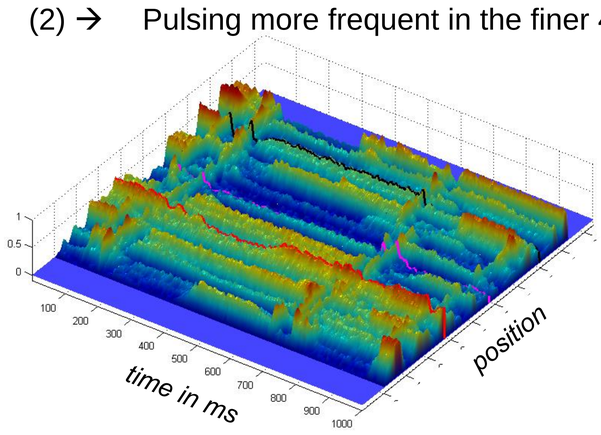


Fig. 6: Temporal evolution of liquid holdup profile in 20 ppi solid foams at position marked in fig. 4.

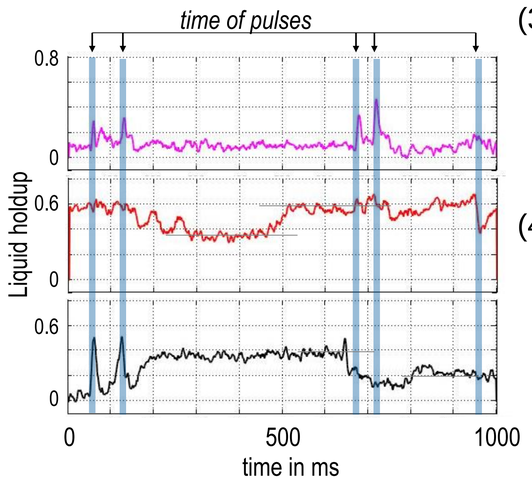


Fig. 7: Temporal evolution of local liquid holdups at position marked in fig. 4.

(3) → Minor fluctuations between liquid pulses indicate shear-stress induced movement of liquid rivulets and films (trickle flow)

(4) → Local re-routing of liquid occurs spontaneously or pulse induced in both directions

CONCLUSION

- With ultrafast CT imaging, pulse and trickle flow in solid foam structures can be investigated
- Uniform initial liquid distribution important for both for pulse and trickle flow in solid foams
- Pulse flow not necessarily changes existing liquid flow routes

Reference

[1] J.R. Blok, A.H.H. Drinkenburg, Chem. Eng. J. 25 (1982), p. 89-99, DOI: 10.1016/0300-9467(82)85025-9

[2] F. Fischer, D. Hoppe, E. Schleicher, et al., Meas. Sci. Technol. 19 (2008), p. 1-11, DOI: 10.1088/0957-0233/19/9/094002.

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Johannes Zalucky | Institute of Fluid Dynamics | FWDF | j.zalucky@hzdr.de | www.hzdr.de