Qualitative and quantitative analysis of liquid flow distribution in SiSiC foams using ultrafast X-ray computed tomography

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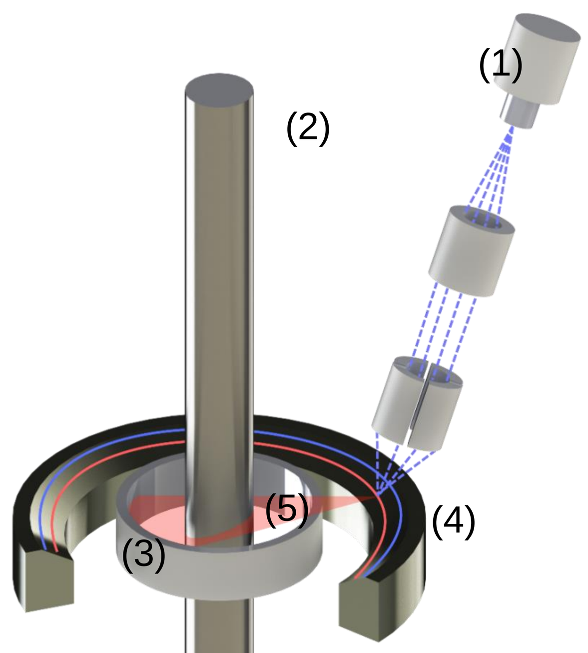
INTRODUCTION & MOTIVATION

- Solid foams are promising novel reactor internals for chemical multiphase processes → high porosity, large specific surface areas, low pressure drop.
- Investigation of liquid distribution/saturation under variation of pore density, liquid and gas flow rates.
- SiSiC foam packings of 0.8 m length and 0.1 m diameter investigated by dual-plane ultrafast X-ray computed tomography recorded with 1000 Hz.

Pore density	Porosity	Pore diameter
20 ppi	0.87	2800 µm
30 ppi	0.89	2070 µm
45 ppi	0.85	1480 µm

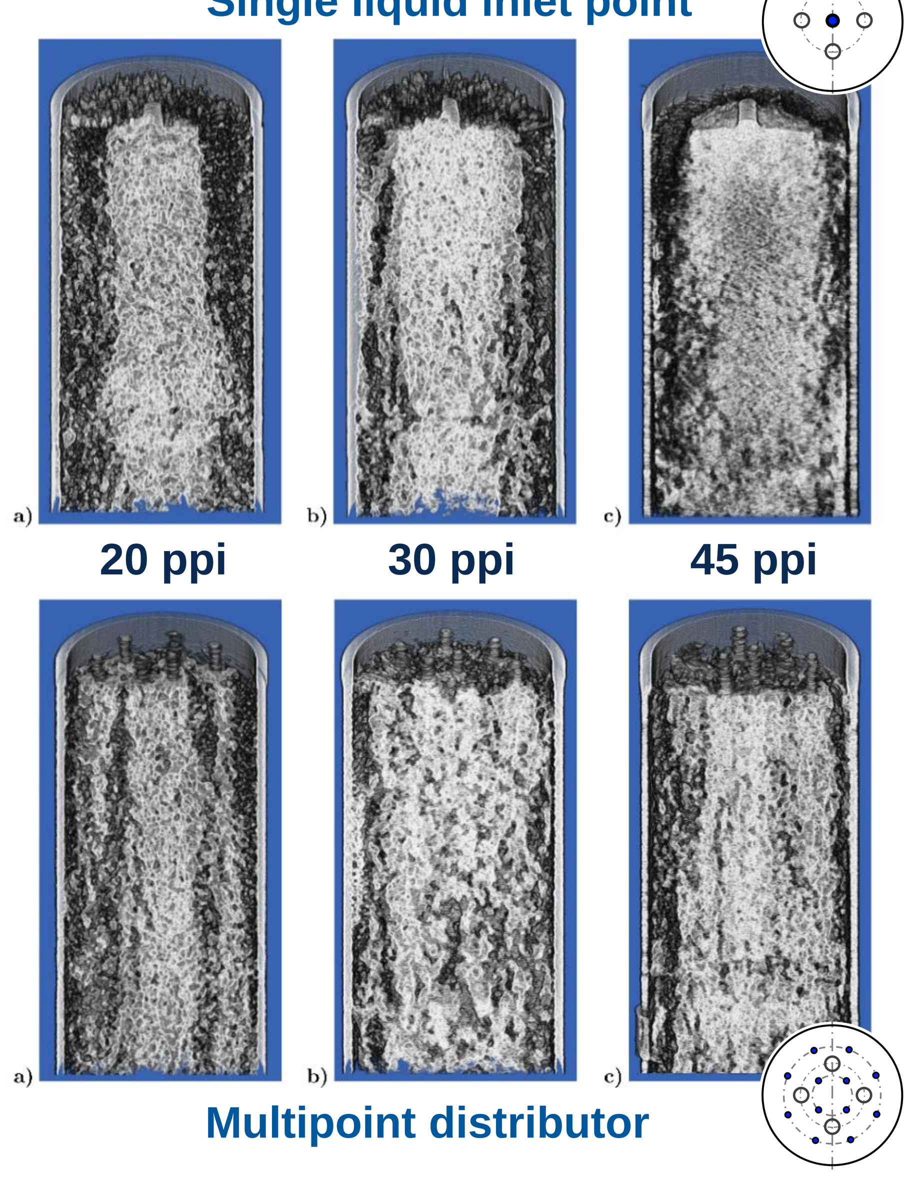


Ultrafast X-ray CT system
(1)…Electron gun
(2)…Measurement object
(3)…Dual-plane detector system
(4)…Target
(5)…X-ray fan beam

LIQUID FLOW DISTRIBUTION

- Single liquid inlet point invokes centered liquid flow and wall-side gas flow.
- Liquid self-distribution increases with higher pore density.
- Liquid backwater on top of 45 ppi foams.

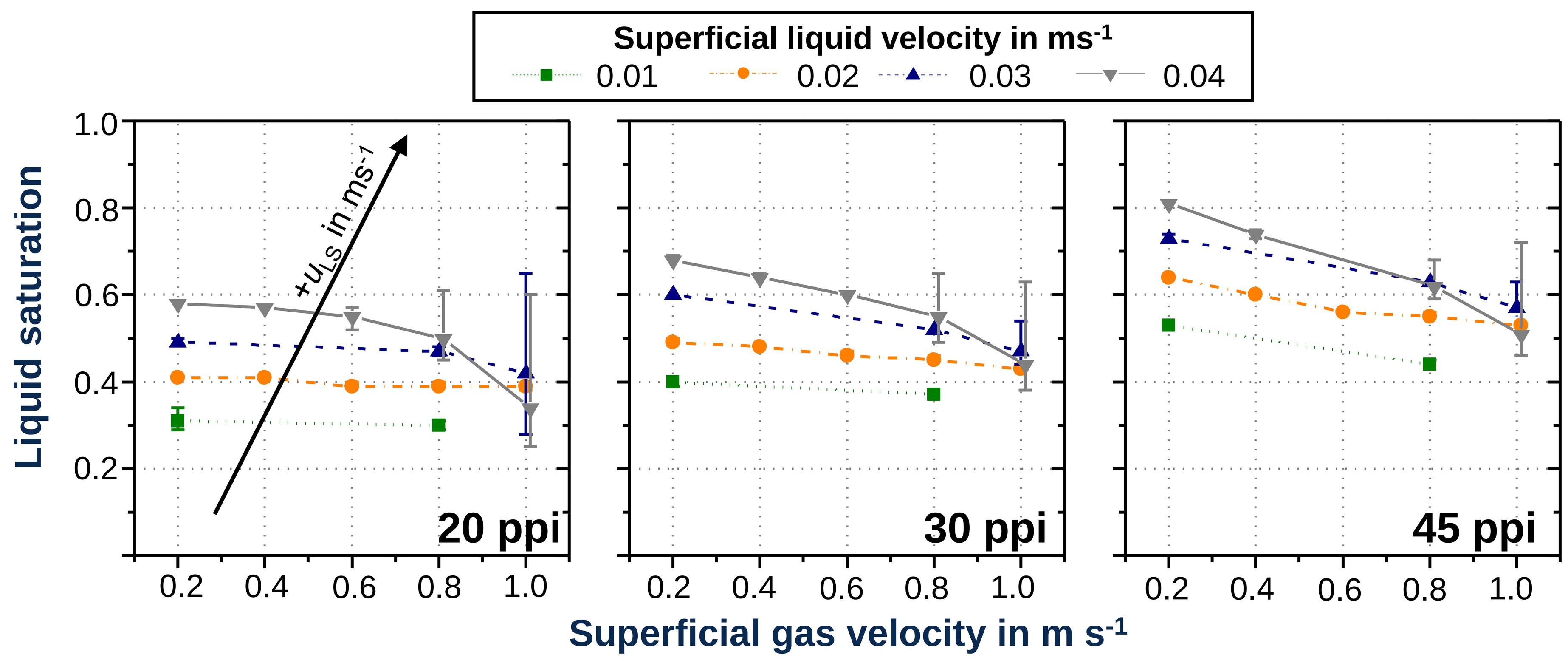
Single liquid inlet point



Multipoint distributor

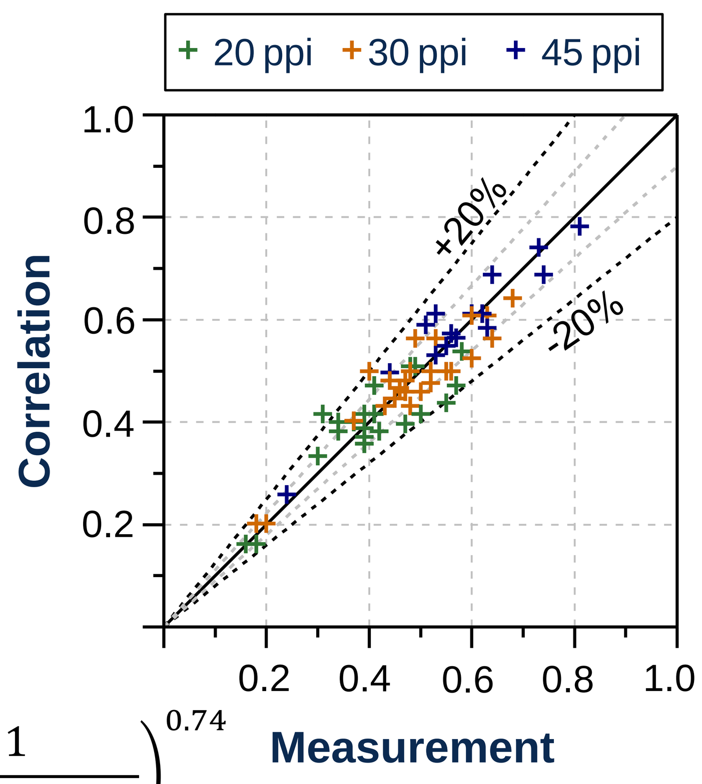
- Multipoint liquid distributor initiates channeled shamrock pattern of liquid.
- In 20 ppi foams, pattern prevails even after first foam element.
- With increasing pore density, pattern blurs along column axis.

LIQUID SATURATION



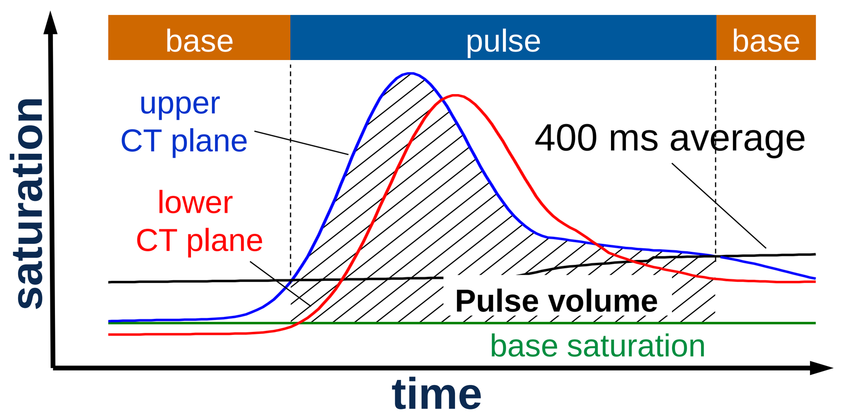
- Liquid saturation increases with higher pore density due to capillary forces.
- In trickle flow, saturation is increased by higher liquid flow rate and lower gas flow rate.
- Saturation fluctuations up to 300% in pulse flow.
- Proposed correlation including static saturation:

$$\beta_L = \left(\frac{1}{4365 \cdot d_{pore}}\right)^{0.52} \cdot \left(\frac{Re_L}{Re_G}\right)^{0.28} + \left(\frac{1}{4365 \cdot d_{pore}}\right)^{0.74}$$

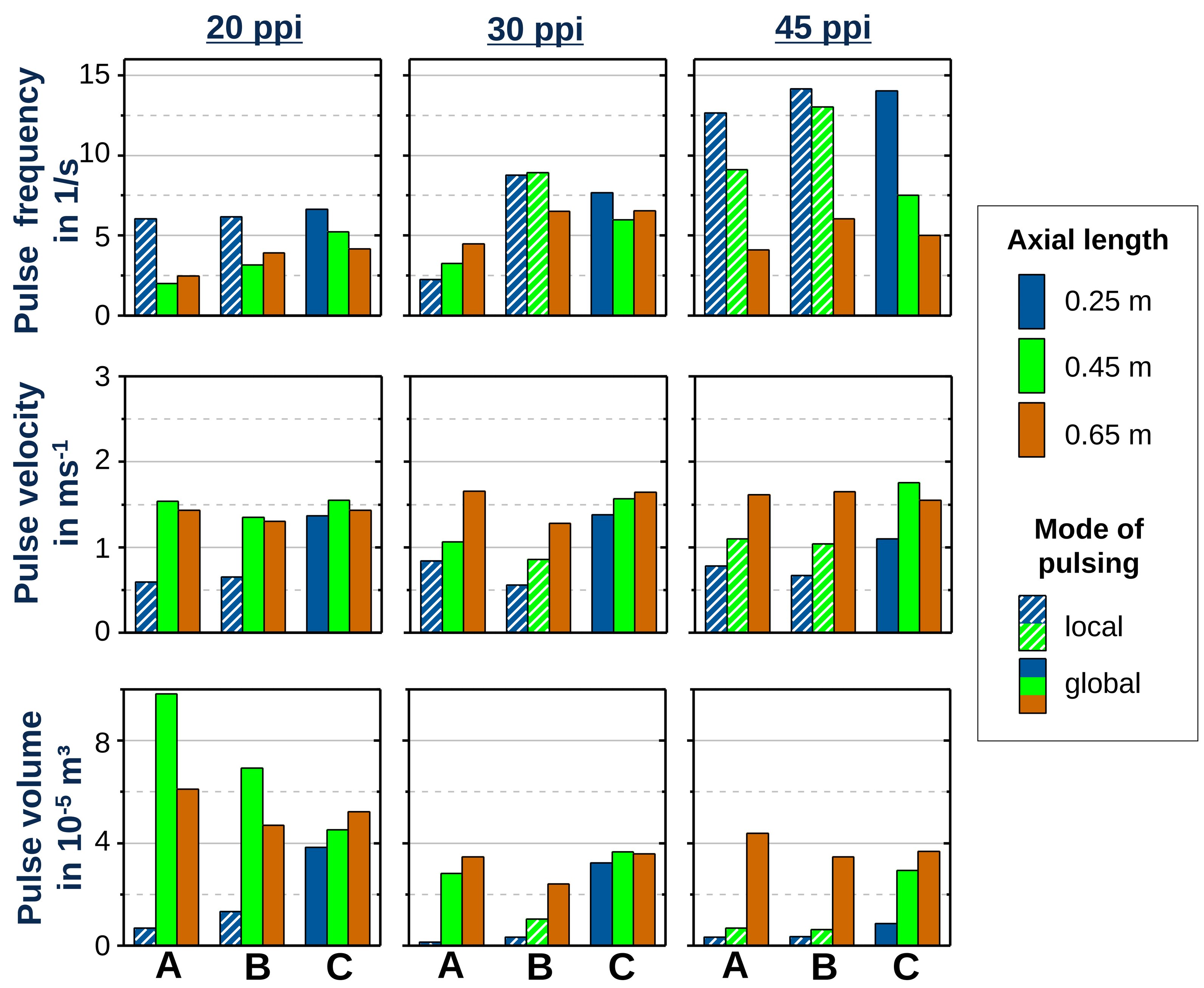


PULSE FLOW REGIME

- Pulse flow = fast passage of gas and liquid rich zones moving through packed bed.
- Liquid rich zones increase heat and mass transfer and alter preferred flow channels.
- Pulse properties depend on mode of pulsing.

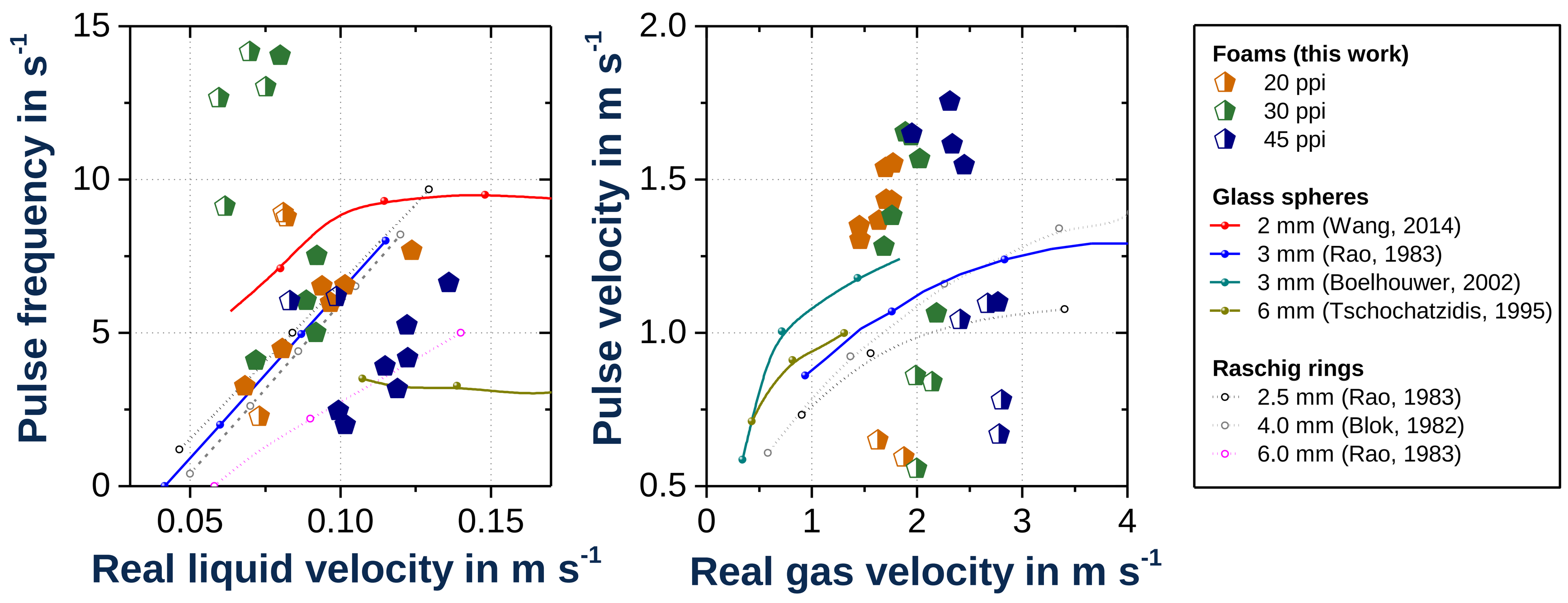


Flow condition	Superficial velocity Liquid	Gas
A	0.03 ms-1	1.0 ms-1
B	0.04 ms-1	0.8 ms-1
C	0.04 ms-1	1.0 ms-1



Main effects

Mode of pulsing	Superficial velocity Average	Superficial velocity Fluctuation	Pulse frequency	Pulse Velocity	Pulse volume
Local	High	Small	High	Small	Small
Global	Moderate	High	Moderate	High	High



- Global pulse frequencies behave similar to conventional packings.
- Global pulse velocities exceed conventional packings dramatically.

CONCLUSION

- Liquid saturation is mostly function of pore density and flow rates.
- Pulse properties depend on mode of pulsing.
- Global pulse frequency and velocity are attributed to similar effects like in conventional packings.

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