Supporting Information

Analysis of Flow Patterns in Structured Zickzack-Packings for Rotating Packed Beds using Gamma-Ray Computed Tomography

Rouven Loll[1,2], Lisa Nordhausen[1], André Bieberle[3], Markus Schubert[3,4], Tobias Pyka[1,2], Jörg Koop[2], Christoph Held[1,], Gerhard Schembecker[2]*

1: TU Dortmund University, Department of Biochemical and Chemical Engineering, Laboratory of Fluid Separations, Emil-Figge-Straße 70, 44227 Dortmund, Germany

2: TU Dortmund University, Department of Biochemical and Chemical Engineering, Laboratory of Plant and Process Design, Emil-Figge-Straße 70, 44227 Dortmund, Germany

3: Helmholtz-Zentrum Dresden-Rossendorf, Institute of Fluid Dynamics, Bautzener Landstraße 400, 01328 Dresden

4: Technische Universität Dresden, Chair of Chemical Process Engineering, 01069 Dresden

*Corresponding author: christoph.held@tu-dortmund.de

Table S1. Total wet pressure drop Δp in the RPB equipped with an unstacked ZZ packing at different rotational speeds n_{rot} at fluid flow rates of tap water and air at 20°C and atmospheric pressure: $\dot{V}_{G,1}$ = 0.5 m^3 h^{-1} and $\dot{V}_{L,1}$ = 0.48 m^3 h^{-1}, $\dot{V}_{G,2}$ = 0.75 m^3 h^{-1} and $\dot{V}_{L,2}$ = 0.72 m^3 h^{-1}, $\dot{V}_{G,3}$ = 1 m^3 h^{-1} and $\dot{V}_{L,3}$ = 0.96 m^3 h^{-1}, $\dot{V}_{G,4}$ = 1.25 m^3 h^{-1} and $\dot{V}_{L,4}$ = 1.20 m^3 h^{-1} and $\dot{V}_{G,5}$ = 1.5 m^3 h^{-1} and $\dot{V}_{L,5}$ = 1.44 m^3 h^{-1}.

n_{rot} / rpm	$\Delta p_{\dot{V}_{G,1},\dot{V}_{L,1}}$ / Pa	$\Delta p_{\dot{V}_{G,2},\dot{V}_{L,2}}$ / Pa	$\Delta p_{\dot{V}_{G,3},\dot{V}_{L,3}}$ / Pa	$\Delta p_{\dot{V}_{G,4},\dot{V}_{L,4}}$ / Pa	$\Delta p_{\dot{V}_{G,5},\dot{V}_{L,5}}$ / Pa
1800	998.61	1057.36	1331.49	1527.29	1953.18
1700	905.61	979.038	1243.37	1493.03	1997.23
1600	797.91	890.924	1150.36	1458.76	2021.71
1500	660.85	807.706	1076.94	1419.60	2041.29
1400	621.68	724.488	998.618	1404.91	2070.66
1300	538.47	646.165	969.247	1419.60	2163.67
1200	469.93	577.632	944.771	1468.55	2222.41
1100	401.40	528.680	944.771	1581.14	2398.64
1000	347.55	489.519	949.666	1590.93	2521.02
900	288.81	450.357	1003.51	1703.52	2555.28
800	239.86	420.986	1042.67	1850.38	2643.40
700	195.80	411.195	1106.31	1904.22	2746.20
600	141.96	411.195	1199.32	2060.87	2800.04
500	112.58	479.728	1253.16	2178.35	2897.95
450	-	548.261	-	2305.63	3113.34
400	132.17	646.165	1429.39	2579.76	4939.24
350	-	1018.19	1693.73	4102.16	5511.98
300	969.24	3265.09	3955.31	4283.29	5981.92

Table S2. Total wet pressure drop Δp at different rotational speeds n_{rot}, at 20°C and atmospheric pressure at fluid flow rates of $\dot{V}_{G,1}$ = 0.5 m^3 h^{-1} nitrogen, $\dot{V}_{L,1}$ = 0.48 m^3 h^{-1} aerated tap water in the RPB equipped with a single-level ZZ packing and at fluid flow rates of $\dot{V}_{G,3}$ = 1.0 m^3 h^{-1} nitrogen, $\dot{V}_{L,3}$ = 0.96 m^3 h^{-1} aerated tap water in the RPB equipped with a single-level ZZ packing and two-level ZZ packing.

n_{rot} / rpm	$\Delta p_{\dot{V}_{G,3},\dot{V}_{L,3},\text{single-story}}$ / Pa	$\Delta p_{\dot{V}_{G,1},\dot{V}_{L,1},\text{single-story}}$ / Pa	$\Delta p_{\dot{V}_{G,3},\dot{V}_{L,3},\text{two-story}}$ / Pa
1800	1302.12	998.61	1081.83
1700	1199.32	900.71	988.82
1600	1101.41	812.60	881.13
1500	1027.98	714.69	788.12
1400	964.35	646.16	709.80
1300	895.81	562.94	631.47
1200	876.23	489.51	558.05
1100	846.86	416.09	484.62
1000	841.97	357.34	425.88
900	881.13	293.71	357.34
800	969.24	249.65	313.29
700	1130.78	220.28	259.44
600	1277.64	195.80	220.28

500	1404.91	181.12	181.12
400	1532.19	190.91	151.75
350	1737.79	234.96	132.17
300	3265.09	533.57	293.71

Table S3. Number of theoretical stages n_{th} at different rotational speeds n_{rot}, at 20°C and atmospheric pressure at fluid flow rates of $\dot{V}_{G,1}$ = 0.5 m^3 h^{-1} nitrogen, $\dot{V}_{L,1}$ = 0.48 m^3 h^{-1} aerated tap water in the RPB equipped with a single-level ZZ packing and at fluid flow rates of $\dot{V}_{G,3}$ = 1.0 m^3 h^{-1} nitrogen, $\dot{V}_{L,3}$ = 0.96 m^3 h^{-1} aerated tap water in the RPB equipped with a single-level ZZ packing and two-level ZZ packing.

n_{rot} / rpm	$n_{th_{\dot{V}_{G,3},\dot{V}_{L,3},\text{single−story}}}$ / -	$n_{th_{\dot{V}_{G,1},\dot{V}_{L,1},\text{single−story}}}$ / -	$n_{th_{\dot{V}_{G,3},\dot{V}_{L,3},\text{two−story}}}$ / -
1800	1.355	1.110	1.031
1550	1.355	1.115	1.022
1300	1.33ß	1.085	1.011
1050	1.290	1.065	1.015
800	1.190	1.090	0.910
550	0.990	0.995	0.856

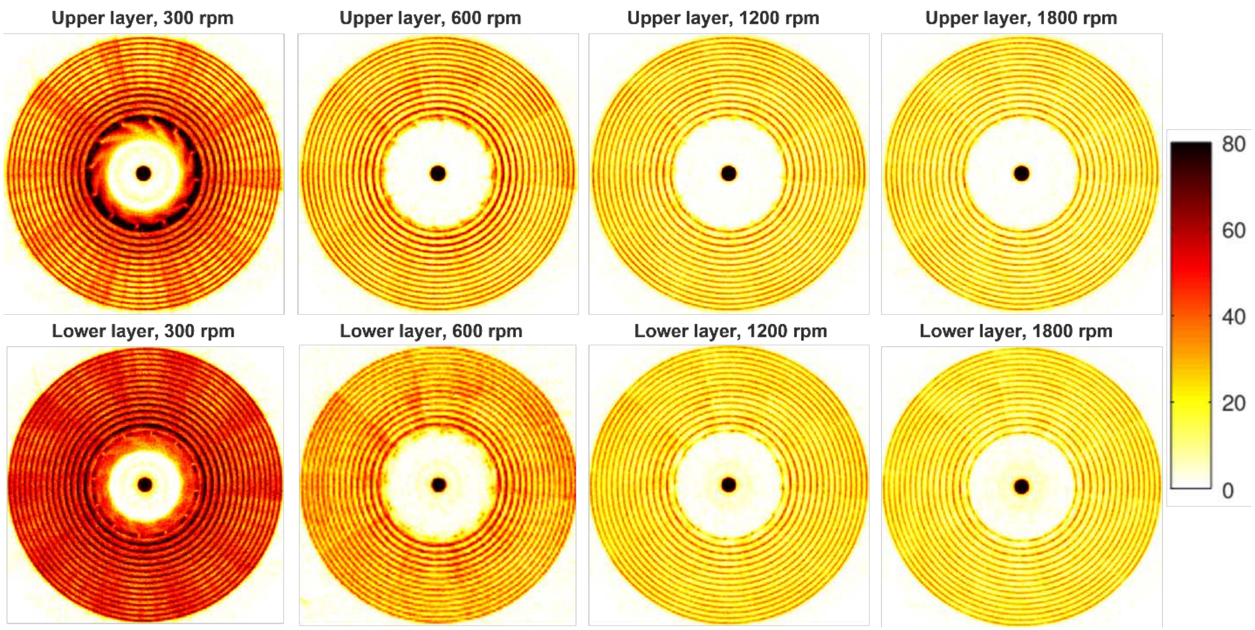

Figure S1. Effect of the rotational speed n_{rot} on the liquid fraction distribution in the upper and lower layer of baffles of the unstacked ZZ packing from 300 to 1800 rpm and constant fluid-flow rates of air: $\dot{V}_{G,3}$ = 1 $m^3\ h^{-1}$ and tap water: $\dot{V}_{L,3}$ = 0.96 $m^3\ h^{-1}$ at 20°C and atmospheric pressure.

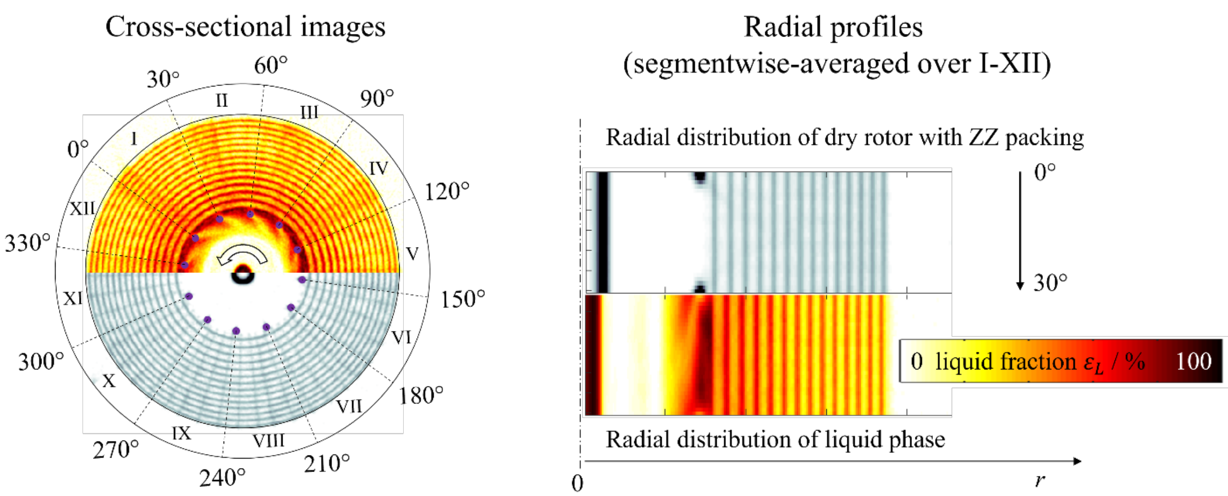

Figure S2. Liquid distribution and corresponding Zickzack structure averaged over twelve 30° segments (I-XII) resulting from the twelve axial struts of the inner packing support ring in the upper layer of baffles of the unstacked Zickzack packing at an air flow rate of $\dot{V}_{G,3}$ = 1 $m^3\ h^{-1}$, a tap water flow rate of $\dot{V}_{L,3}$ = 0.96 $m^3\ h^{-1}$, 300 rpm, 20°C and atmospheric pressure.

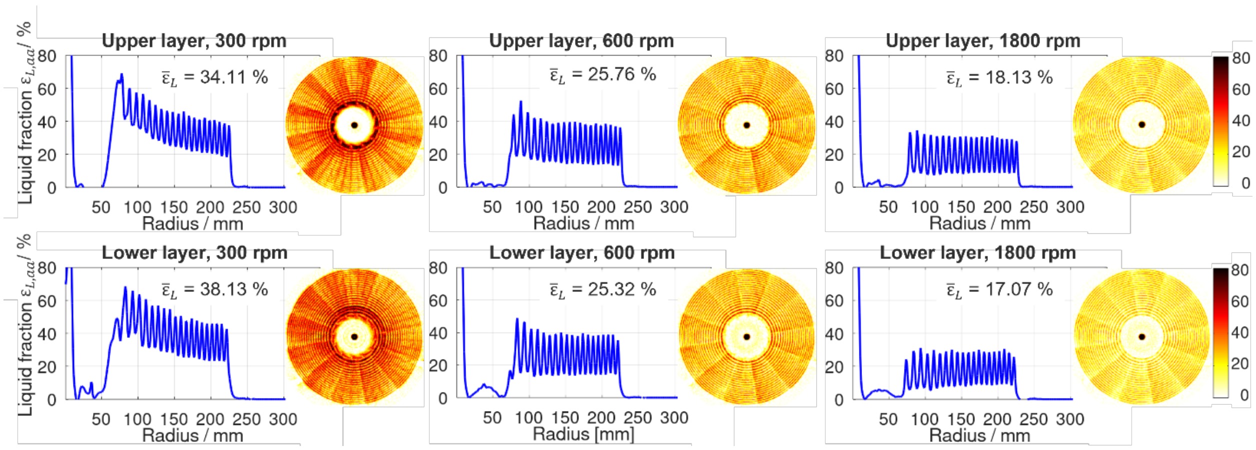

Figure S3. Effect of the rotational speed n_{rot} on the angular-averaged radial profiles of the liquid fraction $\varepsilon_{L,aa}$ and the liquid fraction distribution in the upper and lower layer of baffles of an unstacked ZZ packing with 454 mm outer diameter, made of twelve identical pieces, from 300 to 1800 rpm and constant fluid-flow rates of air: $\dot{V}_{G,3}$ = 1 m^3 h^{-1} and tap water: $\dot{V}_{L,3}$ = 0.96 m^3 h^{-1} at 20°C and atmospheric pressure.

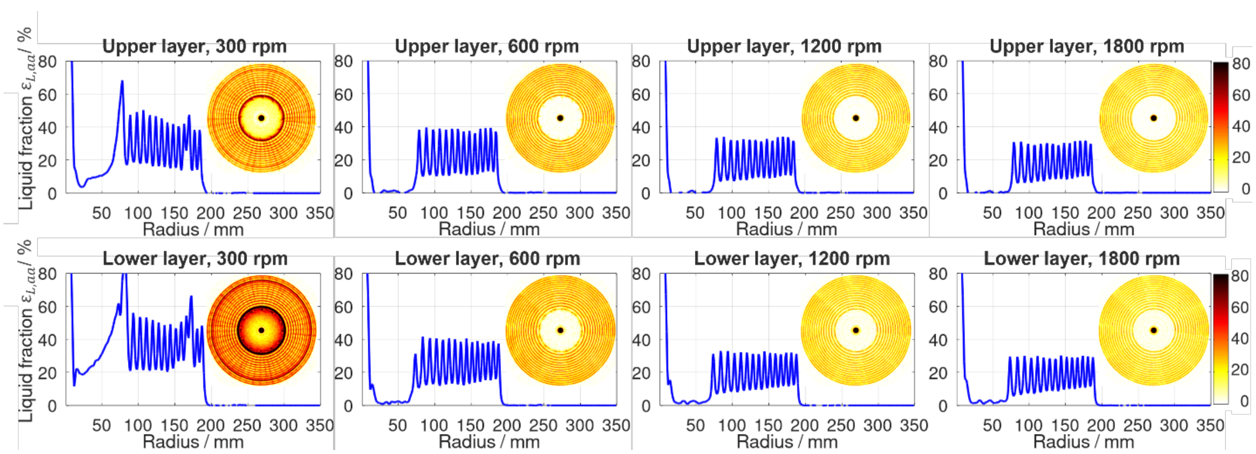

Figure S4. Effect of rotational speed n_{rot} on the angular-averaged radial profiles of the liquid fraction $\varepsilon_{L,aa}$ and liquid fraction distributions in the upper and lower baffle layers of the unstacked ZZ packing at 300 to 1800 rpm and fluid flow rates of air: $\dot{V}_{G,1}$ = 0.5 m3 h-1 and tap water: $\dot{V}_{L,1}$ = 0.48 m3 h-1, at 20°C and atmospheric pressure; an enlarged version of the liquid holdup distribution can be found in the Supporting Information in Figure S4.

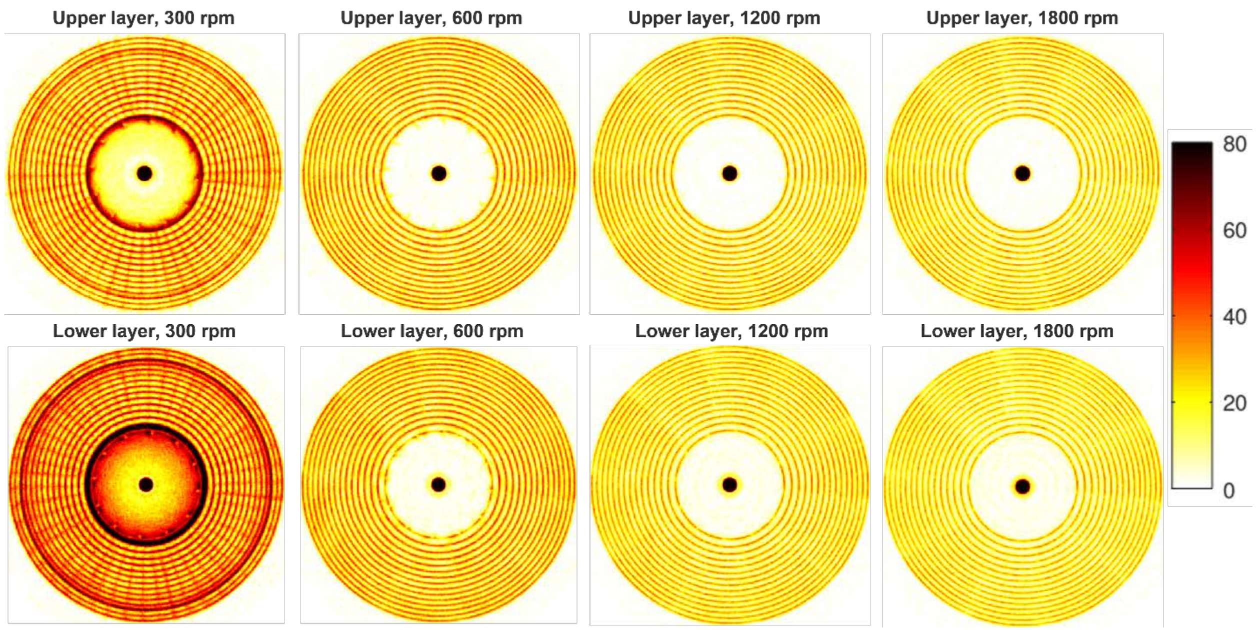

Figure S5. Effect of the rotational speed n_{rot} on the liquid fraction distribution in the upper and lower layer of baffles of the unstacked ZZ packing from 300 to 1800 rpm and fluid-flow rates of air: $\dot{V}_{G,1}$ = 0.5 m^3 h^{-1} and tap water $\dot{V}_{L,1}$ = 0.47 m^3 h^{-1} at 20°C and atmospheric pressure.

Table S4. Effect of rotational speed n_{rot} on the average liquid fractions $\bar{\varepsilon}_L$ in the unstacked ZZ packing at fluid flow rates of $\dot{V}_{G,1}$ = 0.5 m^3 h^{-1} air, $\dot{V}_{L,1}$ = 0.48 m^3 h^{-1} tap water at the upper and lower baffle layers of the unstacked ZZ packing and at fluid flow rates of $\dot{V}_{G,3}$ = 1 m^3 h^{-1} air, $\dot{V}_{L,3}$ = 0.96 m^3 h^{-1} tap water at the upper and lower baffle layers of the ZZ packing at 300 to 1800 rpm at 20°C and atmospheric pressure.

n_{rot} / rpm	$\bar{\varepsilon}_{L\dot{V}_{G,3},\dot{V}_{L,3},\text{lower}}$ / %	$\bar{\varepsilon}_{L\dot{V}_{G,3},\dot{V}_{L,3},\text{upper}}$ / %	$\bar{\varepsilon}_{L\dot{V}_{G,1},\dot{V}_{L,1},\text{lower}}$/ %	$\bar{\varepsilon}_{L\dot{V}_{G,1},\dot{V}_{L,1},\text{upper}}$/ %
1800	13.76	13.05	12.08	11.76
1200	15.57	14.4	13.18	12.67
600	21.14	18.14	15.91	14.77
300	34.27	25.59	24.06	17.73

Symbols

n_{th} = Number of theoretical stages, -

Δp = Total wet pressure drop, Pa

Greek symbols

ε_L = Liquid fraction, %

$\varepsilon_{L,aa}$ = Angular-averaged liquid fraction, %

$\bar{\varepsilon}_L$ = Average liquid fraction in the packing, %