

Supplementary information

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Shear rate distribution in a rocking bioreactor: CFD-based analysis and impact on HL-60 lymphocytes

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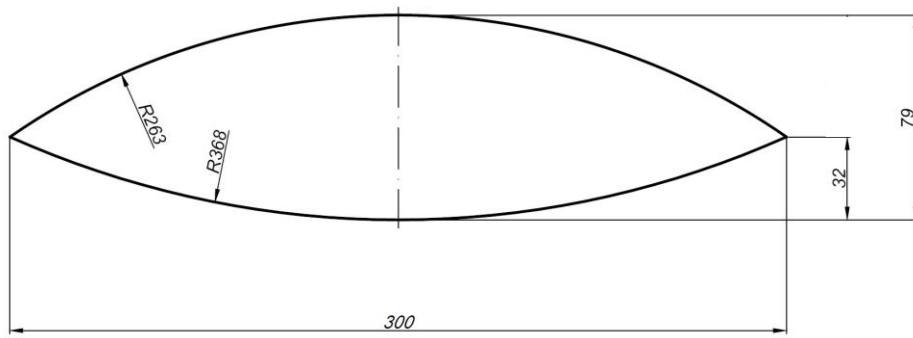


Figure S1. System geometry with dimensions marked. The size is given in millimetres.

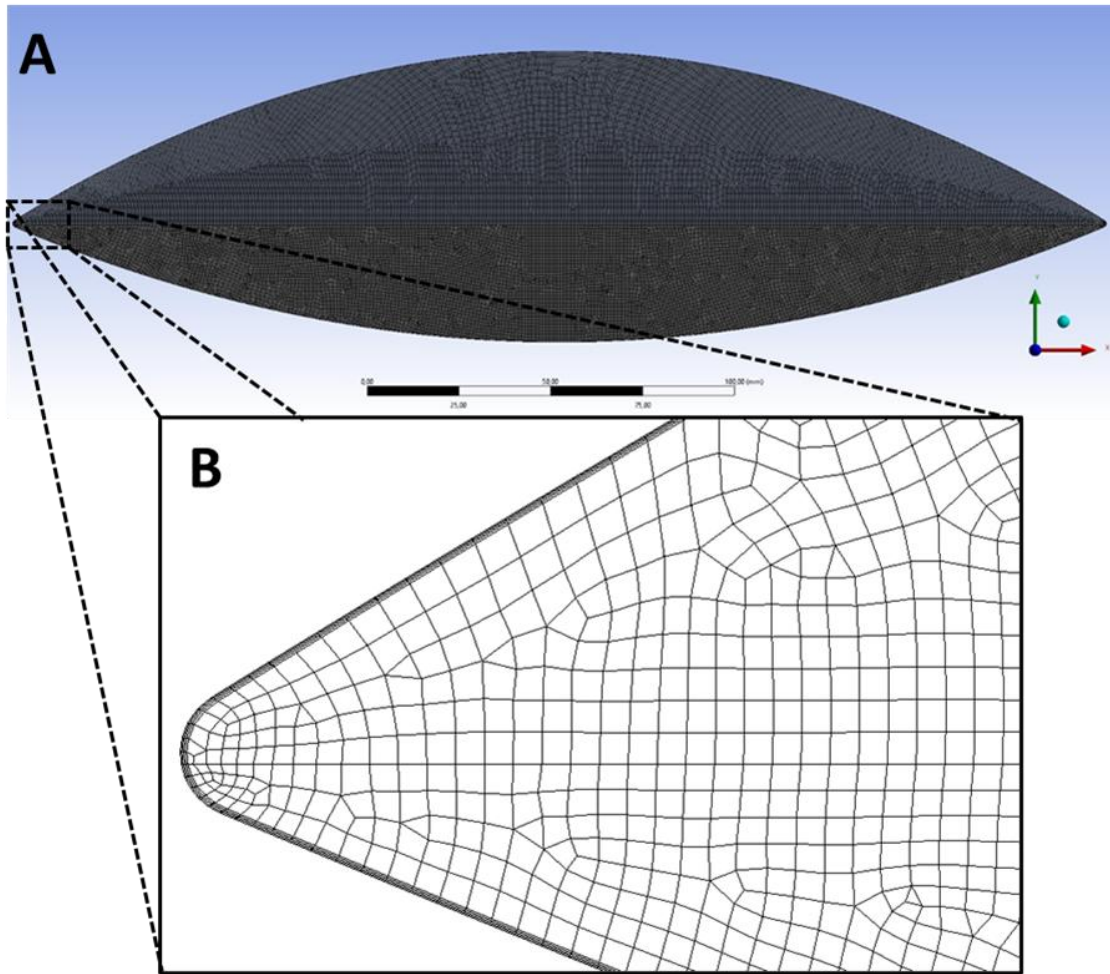


Figure S2. Detailed overview of the bioreactor's computational mesh: complete 2D domain (**A**) and magnified view of the critical corner region, illustrating structured quadrilateral cells, local boundary layer refinement, and seamless conformal fitting to the curved geometry, designed to adequately resolve boundary-layer velocity gradients during wave impact (**B**).

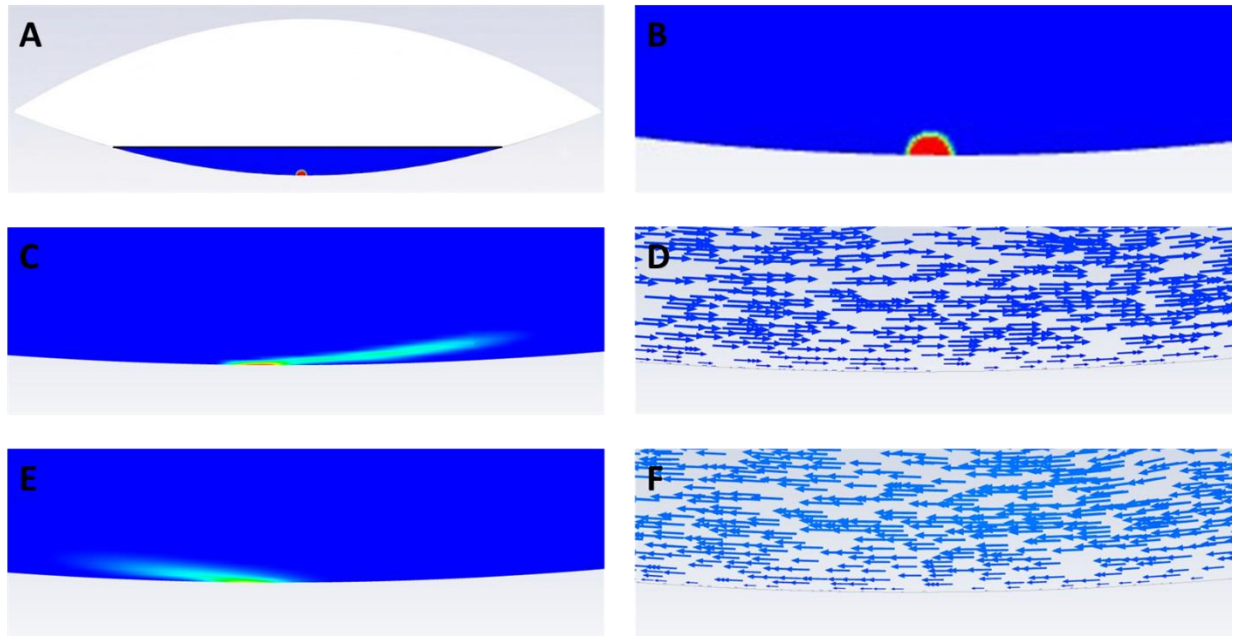


Figure S3. The changes of tracer concentration profile and the velocity vector profile during the first cycle of oscillations for $\alpha = 6^\circ$ and $\omega = 20 \text{ min}^{-1}$, simulated by CFD: initial position of the tracer droplet in CellbagTM 2 L (A); zoom-in on the tracer concentration profile at the beginning of the simulation (B), zoom-in on the tracer concentration profile (C) and the velocity vector profile (D) after 0.75 seconds of the simulation (25% of the oscillation cycle), zoom-in on tracer concentration profile (E) and the velocity vector profile (F) after 2.25 seconds of the simulation (75% of the oscillation cycle). The white region within the CellbagTM 2 L represents the gaseous phase, whereas the blue region represents the 0.3 L liquid phase (15% filling volume). The red dot indicates the starting position of the tracer.

Table S1. Re_L values calculated for wave-type agitation conditions (defined by α and ω).

α	ω	Re_L
[°]	[min ⁻¹]	[-]
6	2	510
12	2	1015
2	20	1704
2	40	3408
6	20	5104
12	20	10152
6	40	10208
12	40	20305

Table S2. Validation of the CellBag CFD model. The t_{95} values and the relative percentage difference determined by CFD and by experiments.

Re_L	t_{95} CFD	t_{95} experimental	Model/experiment difference
[-]	[s]	[s]	[%]
510	280	318	13.57
1015	240	254	5.83
1704	117	137	17.09
3408	26	7.1	-72.69
5104	35	11.2	-68.00
10152	13	10	-23.08
10208	4	4.4	10.00
20305	3	3.7	23.33

Table S3. The summarized values of $\dot{\gamma}_{avg}$, $\dot{\gamma}_{max}$, v_{avg} , and v_{max} estimated based on CFD simulation for Re_L numbers characterized the conditions of the HL-60 cell cultures in the 2L CellBag. The specific values of the studied parameters depend on the stage of oscillation of the CellBag.

Re_L [-]	$\dot{\gamma}_{avg}$ [s ⁻¹]	$\dot{\gamma}_{max}$ [s ⁻¹]	v_{avg} [m s ⁻¹]	v_{max} [m s ⁻¹]
5104	1.5 – 5.0	350 – 2700	0.004 – 0.034	0.04 – 0.18
10152	3.0 – 10	700 – 7500	0.010 – 0.075	0.10 – 0.45
10208	9.5 – 16.5	1600 – 24500	0.030 – 0.105	0.21 – 2.30
20305	14.0 – 22.5	3000 – 31200	0.042 – 0.130	0.45 – 3.40