Supplementary materials to: Microfluidic jet impacts on deep pools transition from capillary-dominated cavity closure to gas pressure-dominated closure at higher Weber numbers

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Mesh Refinement Example

An instant of the simulation domain is rendered in Figure S1. In this particular snapshot the incoming jet is penetrating the stationary droplet (in pink). The right side gives an insight in the adaptive refinement based on errors in parameters of interest. In this case, the adaptation is done iteratively based on convergence error calculated in the interface curvature and momentum. Note that along the interfaces and around the impacting jet in Figure S1 the colour map shows the maximum refinement along the curved interfaces and the jet.

Energy Convergence

To quantify the visual numerical convergence, we calculate the energy distribution over time. Figure S2 shows the energy allocation for different resolutions over the penetration time frame. The energy is normalised by the total energy initially present at highest refinement ($r_0/\Delta = 1024$). From this bar plot we draw multiple conclusions. First we note that over time the total energy is not fully conserved, albeit that increasing the refinement does mitigate the losses. Therefore, we attribute this energy loss to be an inherent part of the numerical method. Regarding the distribution of energy the fractions are comparable, especially for the three highest refinements. This makes evident that the numerical process converges at resolution ($r_0/\Delta = 512$).

The energy calculation was performed as follows. The total energy consists of the total kinetic energy E_k, the total surface energy E_s and the energy dissipation E_d:

$$E_k = \frac{1}{2} \iiint_V \left(\hat{\rho}|u_i|^2\right)\, dV \tag{S1}$$

In the equation above $\hat{\rho}$ is the arithmetic equation for the liquid density of a particular grid cell, taking a value by means of the expression in equation 2.3 in the main paper.

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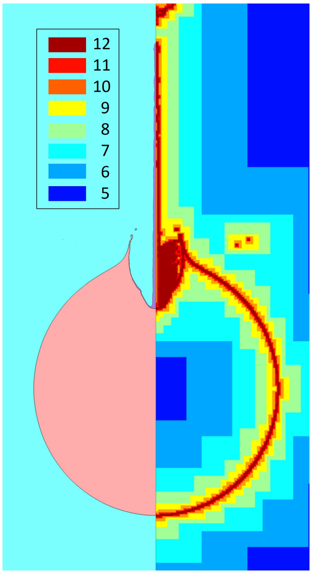

FIGURE S1. Snapshot of simulated domain for $We = 200$, $Re = 2 \cdot 10^4$ and $r_0/\Delta \sim 512$. The left side shows the fraction fields of the droplet, jet and gas in pink, purple and light blue, respectively. The right side displays a colour map of the local refinement. The refinement ranges from level 5 to 12, or $1 < r_0/\Delta < 512$, with decreasing mesh size from blue to red.

$$E_s = \iint_{\partial V} \gamma \, dS \tag{S2}$$

In the above equation, γ, the surface tension coefficient of the interface present in a particular grid cell, takes the value r_j/We. As $We = \frac{\rho_j u_j^2 r_j}{\gamma}$ where the density and downward velocity of the jet, ρ_j and u_j are 1 by definition.

$$E_d = \int_{t_0}^{t} \epsilon_\mu \, dt \tag{S3}$$

Where ϵ_μ stands for the rate of dissipation at a particular instance:

$$\epsilon_\mu = \iiint_V \left(2\hat{\mu} Re^{-1} |D_{ij}|^2\right) dV \tag{S4}$$

With $\hat{\mu}$ the arithmetic equation for the viscosity of a particular grid cell and $|D_{ij}|$ denotes the deformation tensor.

Maximum air velocity for We = 200, 250, 300, 400 and 500

Here we show the maximum air velocity in terms of time for different Weber numbers (200, 250, 300, 400 and 500), in figure S3. The figure shows that the maximum velocity prior impact is constant with a value $u_{g,max} = 4.2 \pm 0.21$ for all Weber numbers. Furthermore the largest maximum gas velocity is observed at the instant of cavity closure.

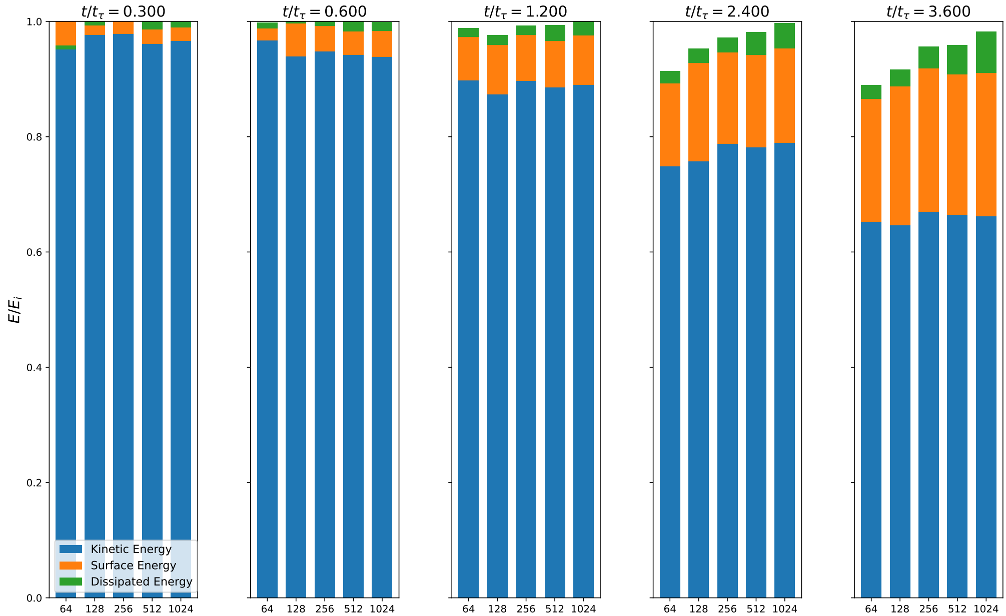

FIGURE S2. Stacked bar plot showing energy distribution per level of refinement. The energy allocation is depicted for various resolutions across the penetration time frame, with normalisation to the total energy initially present at the highest refinement level ($r_0/\Delta = 1024$). Total energy is not perfectly conserved over time, with higher refinement level mitigating this loss.

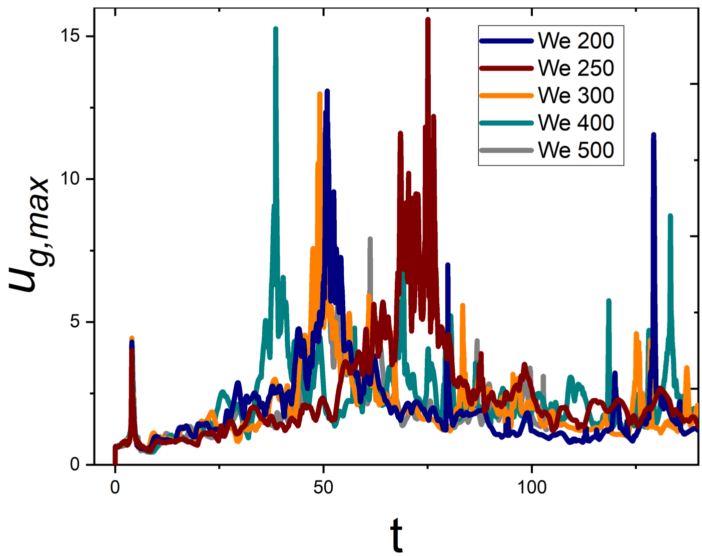

FIGURE S3. Time evolution of maximum gas velocity for different Weber numbers, at Re = 10000. The maximum gas velocity is $u_{g,max} = 4.2 \pm 0.21$ just before jet impact for all We.