Energy conversion during the splash

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Abstract

In an overall effort to model the impact of liquid sprays onto rigid walls, the splashing phenomena plays an important role in determining the velocity and size distribution of ejected droplets from the wall as well as the ejected mass fraction. In practice, increasing the number of splashing droplets in spray impact phenomena can decrease the quality of coated or painted surfaces. During the splash, an uprising crown-like thin liquid sheet develops at the kinematics discontinuity position (a point between the spreading droplet and unperturbed wall film with very high velocity and film thickness gradient). This crown-like sheet is bounded with a free end rim due to the surface tension effect, which generates finger-like jets disintegrating into the secondary droplets. In this study an energy conservation approach is considered for estimating the maximum crown height during the crown development. The energy conservation links the total energy of the impacting droplet and splashing crown. Energy balance ($E_0 = E_{diss} + E_g + E_\sigma$) at the maximum crown height (H^*_{Cmax}) for $h_0{}^* \geq 0.25$ yields

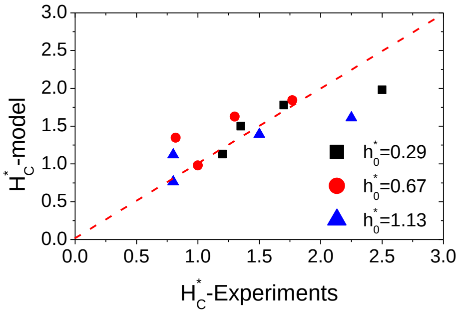
$$\sum_{n=0}^{6} A_n \left(H^*_{C_{max}}\right)^{\frac{n}{2}} = 0$$

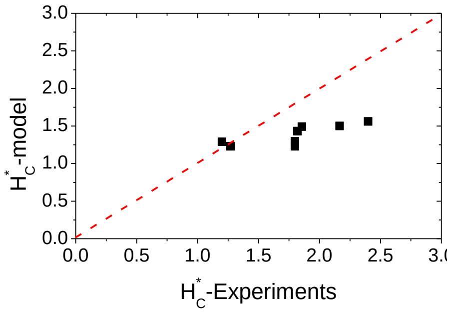
$$A_0 = -\left(\frac{We}{12}+1\right) \qquad A_1 = \sqrt{30}D_f^* \qquad A_2 = \frac{15}{4}\left(\frac{We}{Fr}\right)D_f^{*2} + \frac{3\pi}{2} \qquad A_3 = 11 \qquad A_4 = \frac{3}{4}\left(\frac{We}{\sqrt{\mathrm{Re}}}\right)$$

$$A_5 = 0.55\left(\frac{We}{Fr}\right) \qquad A_6 = \frac{3\pi}{80}\left(\frac{We}{Fr}\right)$$

Which We, Re, and Fr are dimensionless impact parameters defined as: $We = \rho u^2 d_0/\sigma$; $Re = \rho u d_0/\mu$; $Fr = u^2/g d_0$, also $D_f = h_0(1 - h_1/h_0)$.

Numerical solution of the obtained theoretical results in the case of single isolated drops, indicate that the non-dimensional crown height increases nonlinearly with increasing the impact velocity. On the other hand, the non-dimensional crown height decreases slightly with the non-dimensional film thickness, corresponding to the wall film thickness varied in the range 0.25 < $h_0{}^*$ < 1. Theoretical predictions properly estimate the maximum crown height in the case of a splash in isolation, i.e. single drop impact, whereas slightly underestimate in the case of a splash in spray impact conditions. Perhaps in the case of a spray impact, velocity fluctuations inside the wall film cases such differences. Results obtained in this study indicate that the maximum non-dimensional crown height increases linearly with the Weber number before the impact in spray impact phenomena.





Prediction of the maximum non-dimensional crown height estimated from theory as a function of the experimental measurements: splash in isolation (left), and splash in a spray(wright).

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