Head-on impact of liquid drops

Robert D. Schroll

Wendy W. Zhang
Physics Department & James Franck Institute
University of Chicago

Christophe Josserand  Stephane Zaleski
UPMC Univ. Paris 6
Institute d’Alembert

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1. When 2 point particles collide
Outcome controlled by energy & momentum conservation
No dependence on details of interaction
2. At low impact speed, liquid drop bounces like point particle

At high impact speed, thin sheet ejected by colliding drops

Richard and Quéré, Europhys. Lett. 50, 769
3. Relevant parameters (No air effects)

- $U_s$ surface deformation speed  
  \[ \text{surface tension} / (\text{drop size} \times \text{density}) \]^{1/2}  
  \[ 0.1 \text{ m/s} \]

- $U_0$ impact speed  
  \[ 1 \text{ m/s} \]

- $C$ speed of sound  
  \[ 1500 \text{ m/s} \]

\[ \text{Spherical shape until contact with impact plane} \]
\[ \text{incompressible flow} \]

\[ \text{Deformation dominated by inertia} \]
4. Simulating of Drop Impact

**Axisymmetric volume-of-fluid code**
- Solves two-fluid incompressible Navier-Stokes equations
- Air effects negligible on evolution of top surface \((P_g = 0.1 \text{ atm})\)
- Drop interface not broken at impact plane

5. Rapid radial expansion at early times

\[ R_m(t) \approx \left[ \frac{4 \times \text{(drop size)} \times \text{(impact speed)} \times \text{(time since impact)}}{} \right]^{1/2} \]

\[ \frac{dR_m}{dt} \approx \left[ \frac{\text{(drop size)} \times \text{(impact speed)}}{\text{(time since impact)}} \right]^{1/2} \]

What cuts of the diverging expansion speed?
6. Simulation show ejection driven by inertia

volume conservation ➔ pressure variation ➔ liquid ejected radially

\[ \frac{p}{\rho U_0^2} \]

- Small amount of air trapped between drops
  - No effect on top surface
7. Pressure variation at early times

volume conservation $\Rightarrow$ pressure variation $\Rightarrow$ liquid ejected radially

At early times, pressure variation scales with vertical impact speed & radial expansion
8. **Pressure variations at late times**

*volume conservation ➔ pressure variation ➔ liquid ejected radially*

At late times, expansion slows but downward fall slows more dramatically ➔ Pressure decreases more rapidly than early-time scaling form.
9. Surface tension confined to rim & slows expansion

Conclusions

High-speed impact demonstrates fluid properties of drops

Dynamics dominated by inertia
- High pressure at impact plane brakes fall, expels sheet

Surface tension slows expansion