Energy stages of water drop impact

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Introduction

When a liquid drop collides with a solid or liquid surface, the surface generates different results. The results depend on the properties of the drop and the surface, (e.g., energy of drop, deep of surface, viscosity of them, and so on). These results are called “drop impact”. With energy of drop increasing, the results is as following. In our study, we focus on the results of water drop when jet and bead generating (the process B and C).

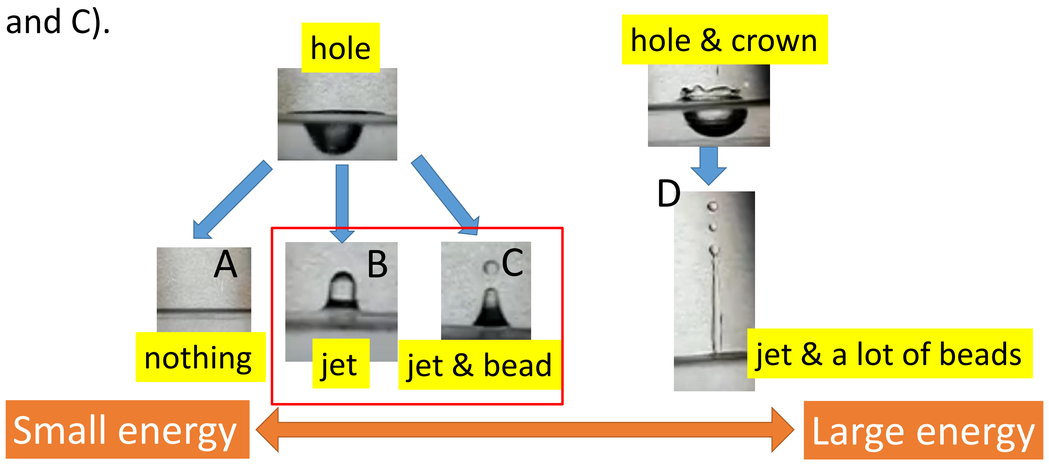


Figure 1. Each result with different initial energy

Principle

The energy change in water drop process can be separated into four stages. Stage 1 is initial energy, which is potential energy and surface energy. The water drop free falls from the dropper. Stage 2 is the kinetic energy when the water drop approaches the water surface. Stage 3 is the energy of cavity. Stage 4 is total energy of jet and beads.

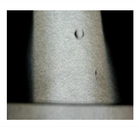
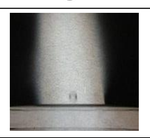
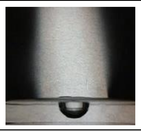
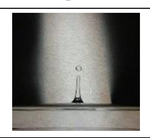
	Stage 1	Stage 2	Stage 3	Stage 4
Image of each stage				
Energy form	mgh + σA	$\frac{1}{2}mv^2$ + σA	mgh + σA	mgh + σA

Figure 2. Schematic diagram of water drop process.

Equipment setup

The dropper is fixed by using tube clamp, and changed the height of water drop. White paper is used to uniform light source. When we do the image analysis, the contour will clear distinguish between it and water drop.

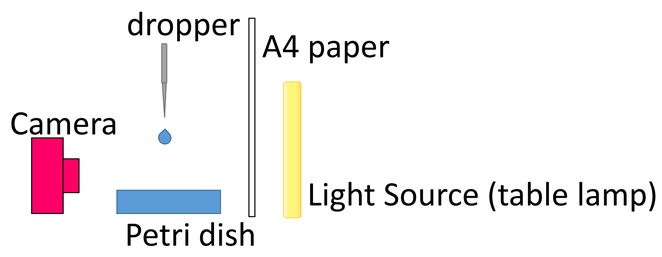
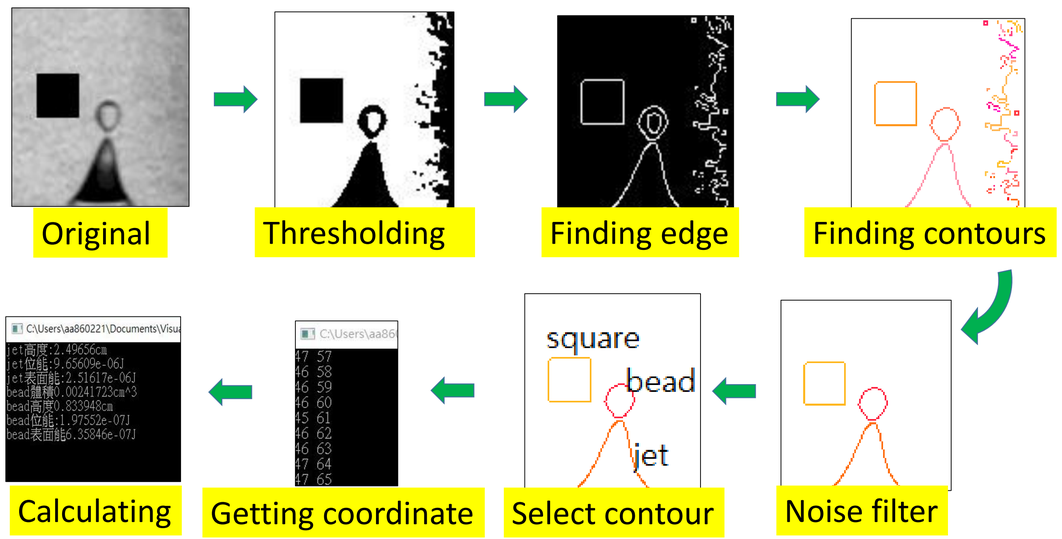


Figure 3. Schematic diagram of equipment

Image analysis

The main program we used for image analysis is C++, and the library is OpenCV. It can analysis many things about image.



Result & Discussion

The figure 4 shows the energy in each stage normalized to the initial energy is initial energy independent (the slope in each energy stage is almost zero). That tells us no matter how much initial energy a drop has, the contribution of each stage is a constant. Therefore, we take the average and standard deviation to draw figure 5 to discuss where the energy lost.

The lost energy between stage 1 and 2 is 5.32%, and it is because of air resistance. The formula of air resistance can be written as $\mathrm{F} = \frac{1}{2}\rho v^2 C_d A$. Where ρ is density of air, v is velocity of drop, C_d is resistance constant, and A is cross-area of drop. Due to we used the velocity of drop before impacting the liquid surface. Therefore, the calculation energy loss caused by air resistance, is a little larger than the result derived from experiments.

Figures 6 and 7 show the energy transfer of former stage into potential and surface energies of latter one. The same point of these two figures are that with the total energy of former stage increasing, the potential and surface energy of latter stage is larger, and the of energy transfers to potential energy is larger than to the surface energy. In the small figure inserted into figure 6, the ratio of potential energy/surface energy is almost constant with different initial energy. It means that the energy transfers into these two energy (U & C) in stage 2 is energy initial energy independent. Moreover, the of energy transfers into potential energy is seven times higher than that of surface energy, that means the influence of the volume of cavity is much larger than how much area cavity has. In figure 7, the result of the energy transfer is similar to figure 6 energy. However, the energy transfer ratios of potential energy/surface energy in stage 2 and 3 are 7.1 and 3.2, respectively. According to figure 6 and 7, the remaining energy between stage 2 and 3 is 53.10%, and lost energy is taken away by water resistance and the wave propagation. The remaining energy between stage 3 and 4 is 72.89%, and the lost energy is mainly taken away by wave propagation. We find the lost energy in stage 3 to 4 is smaller than in the stage 2 to 3 is because the impact of the water drop generates a higher amplitude wave compared with the wave amplitude generated by jet and beads.

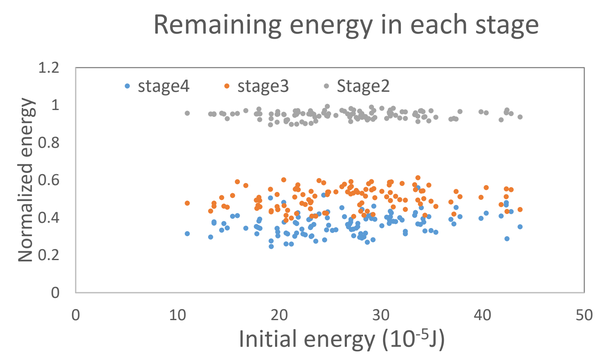


Fig.4 Remaining energy in each stage (normalized to initial energy)

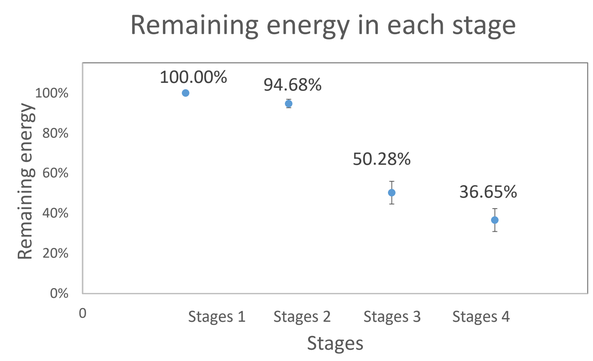


Fig.5 Remaining energy in each stage

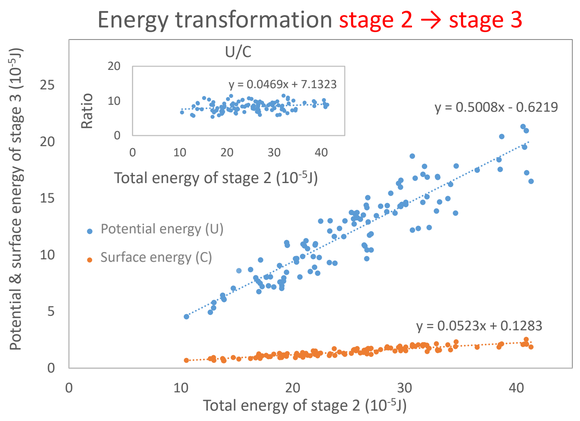


Fig.6 Energy transformation from stage2 to stage 3

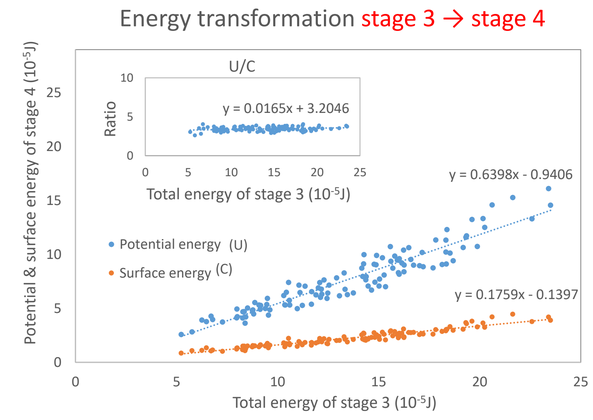


Fig.7 Energy transformation from stage3 to stage 4

Conclusion

1. Although initial energy is difference, the remaining energy’s proportion and the ratio of potential energy/surface energy are the same in each stages.
2. The energies of jet and bead remain less than 40% during drop impact process.
3. The lost energy between stage 1 and 2 is 5.32%, and it is because of air resistance. The lost energy between stage 2 and 3 is 44.4%, and it is taken away by water resistance and the wave propagation. The lost energy between stage 3 and 4 is 13.63%, and it is because of the wave propagation.

Reference

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