Shorter Contribution

On the Behavior of Water Droplets during Collision with a Large Water Drop

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Introduction—It is well known that the collision of cloud droplets with raindrops is an important factor in the growth of raindrops, however, colliding cloud droplets are not always captured by the raindrops. The problem of whether colliding droplets are captured or rejected is not expected to be resolved theoretically by hydrodynamical consideration.

Sartorl1 and Schotland2) carried out model experiments to measure the collision efficiency, but from those experiments no clue to the coalescence was obtained, because the collision of drops was not caused to occur in air, but in oil or a sugar solution. It is considered that the coalescence is markedly influenced by the surface tension of water in air.

The present authors observed the behavior of water droplets by slow shutter speed photographs during their collision with a large stationary water drop. Some difficulties remain, for example, the relative motion of the water droplets and the water drop was not exactly the same as that of natural cloud droplets and raindrops.

Method—Water droplets of diameter ranging from 50 to 1000 microns were sprayed from a nozzle under constant pressure. The droplets fell with their respective terminal velocities into a cylindrical box as shown in Fig. 1. Some of the droplets collided with or touched a large water drop of diameter about 5 mm which was set on a piece of reed leaf of dimension 4 x 4 mm, as shown in Fig. 1. A piece of leaf was fixed on the top of a thin glass tube with “Cemedine” (adhesive) as shown in the area enclosed by dotted lines in Fig. 1. The piece of reed leaf being hydrophobic, served to maintain a spherical upper surface on the water drop. Tap water was used both as the water droplets and as water drops.

Results—At the beginning of the experiment, water droplets of diameter near 1 mm were selected so that the terminal velocity of the droplets was equal to the difference between the droplets’ terminal velocity and the drop’s terminal velocity. However, it was found that droplets of diameter near 1 mm disrupted the drop by shock in almost all cases when they collided with it. The result suggests the possibility that large unstable raindrops may be disrupted by shock when they collide with smaller raindrops during fall. Therefore, smaller water droplets of diameter 50 to 200 microns were used in the later experiments. In those experiments, it was noted that the behavior of water droplets of diameter smaller than 100

Fig. 1. Vertical section of apparatus. Field of view of camera is shown by dotted lines.
microns was clearly different from that of droplets with diameter near 200 microns. The former will hereafter be called "smaller droplets" and the latter "larger droplets."

Larger droplets were mostly captured when they fell on or near the center of upper surface of water drop. For a short period after the collision, the upper surface of the drop oscillated violently. One may see in Fig. 2 a sort of wen on the upper surface of the drop owing to the oscillating motion. It was also observed that small air bubbles were introduced into the drop when droplets coalesced with it. Sometimes when droplets fell on the outer area of the surface or touched the side of the water drop, they cut off a part of the water drop. An example is shown in Fig. 3, where one sees that a droplet which fell close to the side surface of the drop left a sharp zigzag trajectory and tore off a part of the drop. The zigzag trajectory indicates perhaps that the droplet slipped and rotated when it touched the surface of the drop.

When smaller droplets fell on a water drop, they were captured rather quietly and did not cut off a portion of the drop even if they fell near the side surface of the drop. But some of them which collided were rejected from the upper surface of the drop. It seems that whether a droplet is captured or rejected depends on some delicate condition, perhaps on slight impurity of water used.

Numerical values of the results obtained are in the following table.

<table>
<thead>
<tr>
<th>Diameter of droplets</th>
<th>Number of Droplets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near 200 µm</td>
<td>Captured 21</td>
</tr>
<tr>
<td>Smaller than 100 µm</td>
<td>Tearing off 13</td>
</tr>
<tr>
<td></td>
<td>Rejected 0</td>
</tr>
<tr>
<td></td>
<td>Total 34</td>
</tr>
<tr>
<td></td>
<td>Captured 53</td>
</tr>
<tr>
<td></td>
<td>Tearing off 0</td>
</tr>
<tr>
<td></td>
<td>Rejected 24</td>
</tr>
<tr>
<td></td>
<td>Total 77</td>
</tr>
</tbody>
</table>

**Considerations**—The results listed in the table show that the larger the droplets are, the more often they tear off a portion of the drop and that the smaller the droplets, the more often they are rejected when they collide. The larger droplets and the smaller droplets used are far smaller than droplets of diameter near 1 mm whose terminal velocity is roughly equal to the relative velocity of the droplets to drop of diameter 5 mm. Therefore, it is supposed that in nature large raindrops of diameter about 5 mm may be more often disrupted by collision with smaller raindrops of diameter about 1 mm than stated in the table.

Comparing the result from the experiments with natural cases, the following differences are noted.

i) The trajectory of droplets is not the same as in nature, because there is not relative air flow around the drop, and the shape of the upper surface of the drop is, to some extent, different from the lower surface shape of falling raindrops.

ii) The surface tension of the water drop was different from that of raindrops, because tap water was used.

iii) The colliding velocity of droplets was smaller than that of natural case. Cloud droplets are considered to collide with raindrops with more rapid speed.

iv) The water drop was set on a piece of reed leaf, although the piece was very thin. Therefore, the unstability of the drop to shock was perhaps magnified.

v) The water droplets were electrified when they were sprayed, although the drop was connected to earth naturally.

Those imperfections described above must await further research.

**References**


Trajectories of Water Droplets and Side View of Water Drops

Fig. 2. Upper surface of water drop vibrated owing to the shock of a droplet's fall.

Fig. 3. A droplet touched the right side surface of drop, leaving a zigzag trajectory, then cut off a part of the drop.

Fig. 4. Three droplets were rejected from the upper surface of drop.
微水滴と大水滴の衝突状態について

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雲粒が雨滴と衝突しても、必ず雨滴に捕獲されるとは限らない。この現象をなるべく天然に近い状態で実験的に調べるために、下から支えられた直径 5 mm 前後の水滴面に直径 1 mm 前後の水滴を自由落下させた。両水滴の相対自由落下速度が後者の水滴の自由落下速度に大体等しいからである。この際予期に反して大きな力の水滴は殆ど例外なく分裂してしまった。そこで相対速度を考慮に入れることなく直径 50 μ 程度と 200 μ 程度の微水滴を上記の大水滴表面におとして捕獲の有無を調べた。50 μ 程度の微水滴は大半捕獲されたがその半数ははちきりとれた。これは不純物の影響かも知れない。200 μ 程度の微水滴でははちきりとれることはなかったが、すれすれに衝突する時は大水滴の一部を削りつつ落もることも多い。この実験は天然の状態とは相対速度や気流について相当異なるのでなお装置を改良、継続中である。