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Sequential impact of two magnetic fluid droplets on a paper surface

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Abstract

Characteristics of the sequential impact of two magnetic fluid droplets on the paper surface under an applied magnetic field were studied with a three-dimensional motion analysis system. Effect of a magnetic field on the phenomenon of sequential impact of two droplets were revealed.

Keywords: Magnetic fluids; Impact phenomena; Magnetic drops

1. Introduction

The characteristics of a liquid drop impacting on a solid surface are of fundamental interest and great importance in many technological applications, including spray painting, spray coating, spray cooling, spray forming, and annealing. Therefore, extensive investigations on the impact phenomena of liquid drops with solid surfaces have been conducted by a number of researchers [1–3]. However, no study has been published on the impact phenomena of a magnetic fluid drop on the solid surface under an applied magnetic field except for our previous paper [4,5]. In our previous paper, a single droplet impacting of magnetic fluid on the paper surface subject to a magnetic field has been investigated.

In the present paper, the characteristics of the sequential impact of two magnetic fluid droplets on the paper surface under applied magnetic fields are studied experimentally.

2. Experimental apparatus and procedures

A schematic diagram of the experimental apparatus is shown in Fig. 1. Magnetic fluid drops were formed with a 25-ml burette. The first droplet of magnetic fluid fell on a piece of paper that was bounded to the hard rubber mat. A disk thin layer of magnetic fluid was formed by the impact of first droplet under non-magnetic field. The second droplet of magnetic fluid fell sequentially on the disk thin layer produced by the first drop impact. In case of applied magnetic field, the first drop impact formed a number of spikes of magnetic fluid. The impact velocity of the droplet was varied by the change of the height from which it fell. A permanent magnet installed under the rubber mat was used to magnetize the magnetic fluid drop. The impact phenomena of magnetic fluid droplets were analyzed by a three-dimensional motion analysis system. The impact phenomena were recorded at 13 500 frames per second, and a series of frames of the phenomena were analyzed by the motion grabber and a personal computer. Sample magnetic fluid used in the experiments was kerosene-based ferricolloid HC-50.

3. Experimental results and discussion

3.1. Impact phenomena without a magnetic field

Fig. 2 shows a sequence of photographs of the impact phenomena produced by a second drop impact on the disk thin layer of magnetic fluid without a magnetic field. In Fig. 2, B is the magnetic flux density, H is the

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fall height, and the stage which is nearest to the first instant of contact between the drop and the target is marked as $t = 0$ s. As the second droplet touches the surface of magnetic fluid pool produced by a first drop impact, a liquid film spreads outwards. The crown around the deforming droplet is formed and grows in time. Subsequently, the crown breaks up into many tiny droplets. These impact phenomena are similar to splashing phenomena of the drop impact onto very thin liquid film reported by Wang and Chen [6].

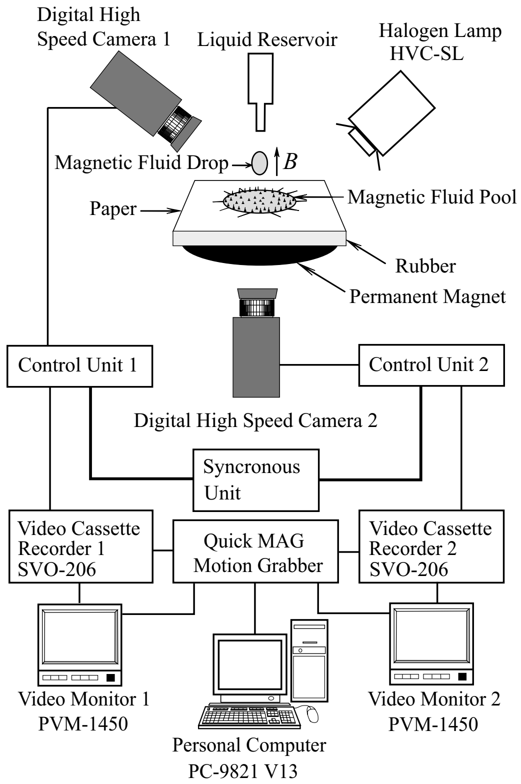

Fig. 1. Schematic diagram of experimental apparatus.

3.2. Impact phenomena with a perpendicular magnetic field

Under an applied magnetic field, distinct interfacial phenomena for sequential impact were observed. Fig. 3 shows a sequence of photographs of second drop impact with a perpendicular magnetic field to the target surface. The first drop impact of magnetic fluid makes many spikes on the target surface. The falling drop of magnetic fluid is elongated by the action of the magnetic field. After drop impact, the liquid flows radially outward, and the crown is formed. However, the crown breaks up at the lower part of the crown wall. The breakup of the crown makes many elongated tiny droplets. These droplets fall again, and form widely spreaded spikes.

Fig. 4 shows how the radius of the base of the magnetic fluid spread produced by the first drop impact varies with time measured from the moment of impact. At higher magnetic fields, the radius of the base of magnetic fluid spread, $2r_m$ slowly increases, but the final spread diameter is larger compared with the case of lower magnetic fields. In the present experimental condition ($H \leqslant 1$ m and smooth target surface), the first drop impact has never produced the same crown as shown in Fig. 2. These results have already been reported by the authors [4]. Fig. 5 shows the development of crown edge during spreading of magnetic fluid at the second drop impact. The second drop impact onto the thin liquid film produced by the first drop impact under the non-magnetic field makes the bowl-shaped

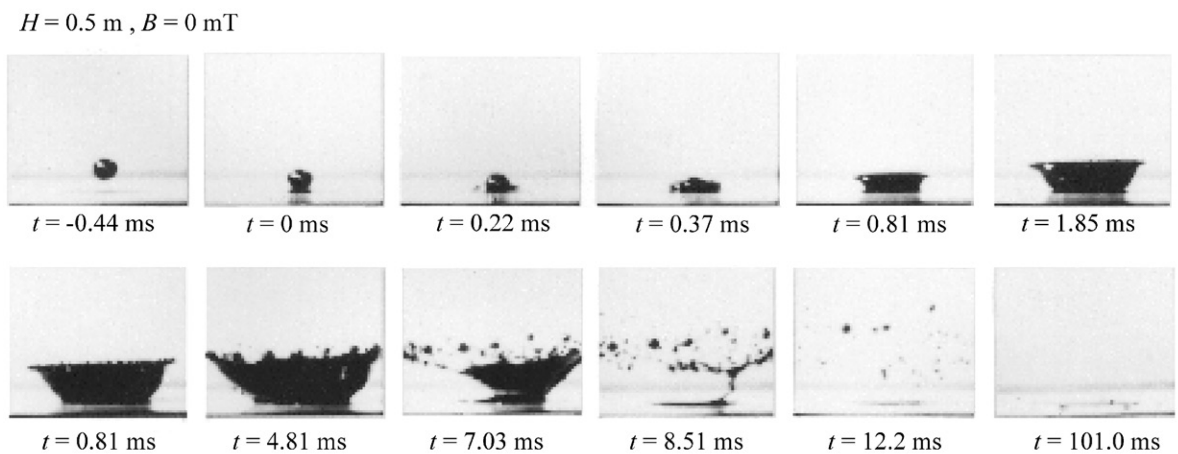

Fig. 2. Photographs of a sequence of stages in the second drop impact without a magnetic field.

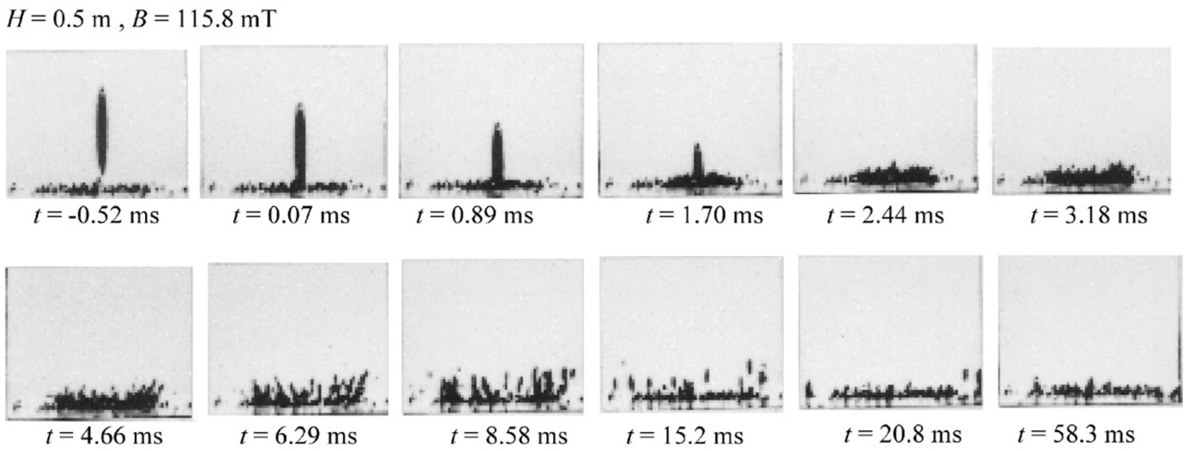

Fig. 3. Photographs of a sequence of stages in the second drop impact with a magnetic field.

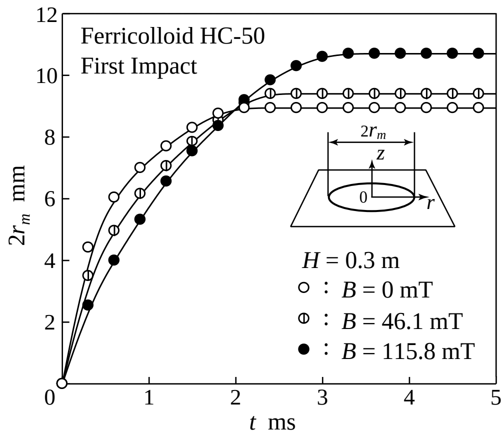

Fig. 4. Evolution of magnetic fluid spread during the first drop impact.

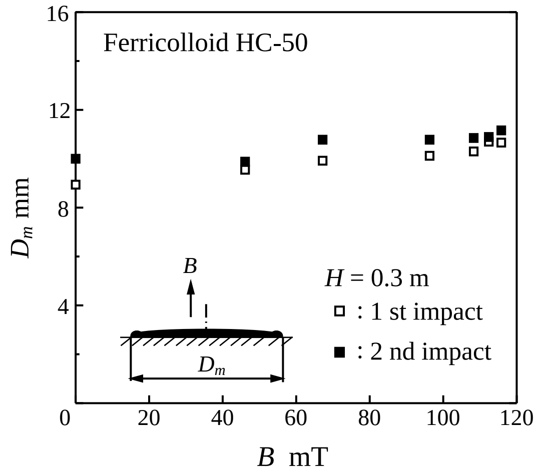

Fig. 6. Maximum diameter of the magnetic fluid spread formed by the drop impact.

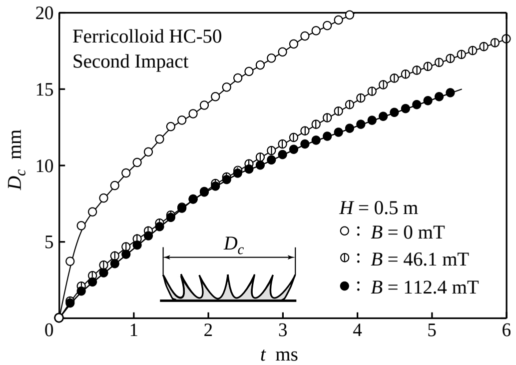

Fig. 5. Growth of magnetic fluid crown edge during spreading at the second drop impact.

crown as shown in Fig. 2. On the other hand, under the applied magnetic fields, the second drop impact produces the complicated crown as shown in Fig. 3. Such complicated crowns are caused by the applied magnetic field and many magnetic fluid spikes produced by the first drop impact. The distributed spikes of magnetic fluid have an effect on the impact phenomena as if the drop impinged upon the rough target [5]. It can be seen from Fig. 5 that the time development of the crown diameter D_c decreases with the increase of the magnetic flux density.

Fig. 6 shows effect of the magnetic field on the maximum spread area of magnetic fluid with sequential drop impacts. It can be seen that the maximum diameter of the magnetic fluid spread, D_m

left by the second drop impact increases with the applied magnetic field.

4. Conclusions

After the second drop impact on the disk thin layer of magnetic fluid, the crown around the deforming droplet was easily formed without a magnetic field. On the other hand, under the applied magnetic field distinct interfacial phenomena for sequential impact were observed; that is, the complicated crown was formed and the breakup of the liquid crown made many spikes of magnetic fluid.

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