Determination of the effectiveness of high-speed cameras for identifying ejection particles during splash with regard to the sticky paper method

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Introduction

The phenomenon of splash caused by water drop has been widely studied in recent years. There are many measurement methods, including the method based on the use of so-called high-speed cameras. Due to the possibility of recording of the phenomenon with a high time frequency (thousands of recorded frames per second), this method provides detailed information about the process of splashed particles, which were previously unavailable. These include, among others, precise tracking of single ejected particles, determination of their ejection angle, displacement distance, and division of splashed elements into groups depending on the place or moment of ejection from the particle bedding. Despite the numerous advantages of the method, there is no information about the percentage of splashed particles that the cameras are able to detect and identify. In order to determine such effectiveness, it is necessary to have a reference method that guarantees 100% identification of splashed particles.

The aim of this work was to determine the effectiveness of high-speed cameras in identification of particles ejected from the granular bedding during the water drop impact. Sticky paper was used as a reference method.

Materials and method

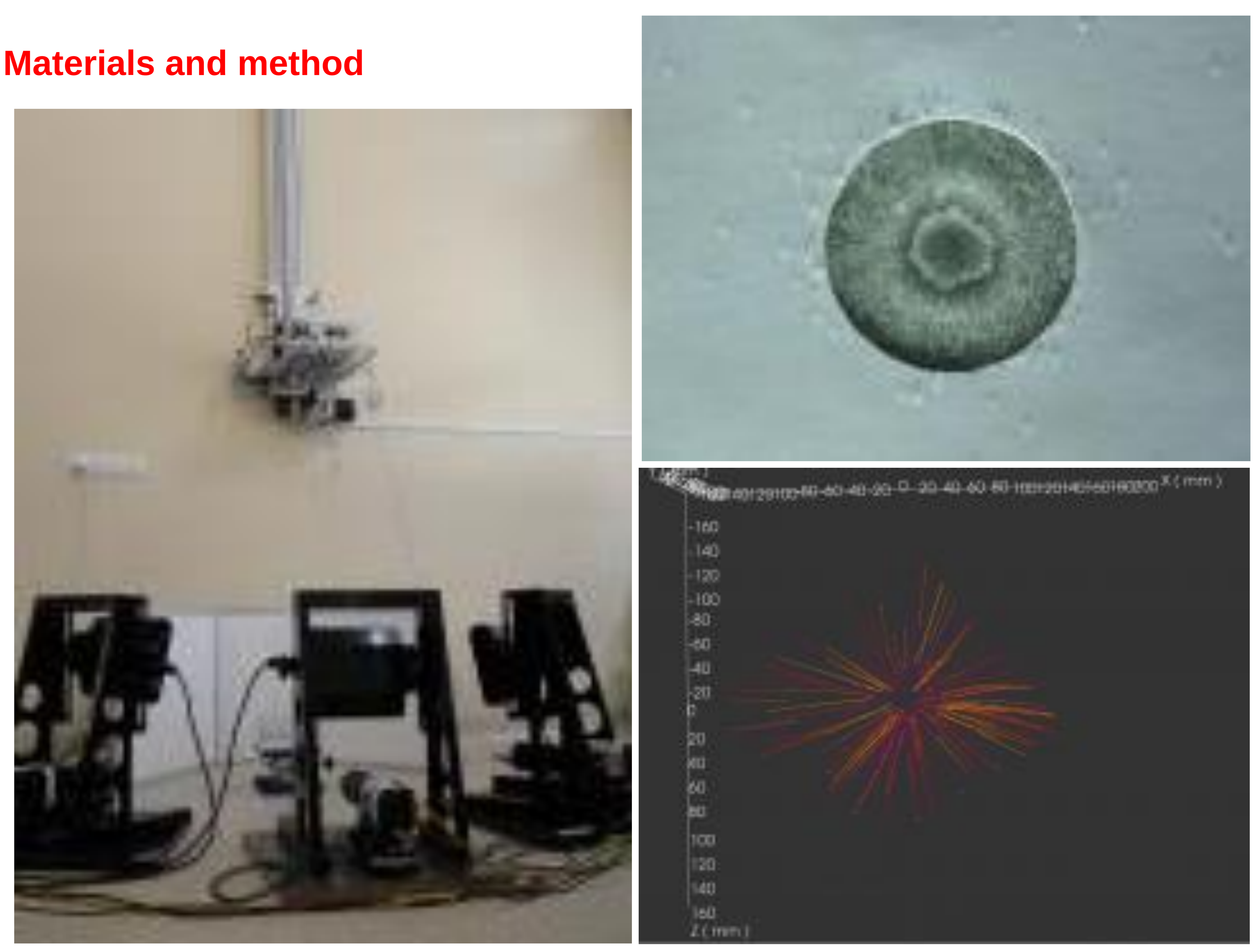

Fig.1.a: *The set of high-speed cameras with lighting and water dosing system;* **b:** *splashed glass beads on sticky paper;* **c:** *the trajectories of particles.*

Dry spherical glass beads (425–600 μm size range), which were placed into an aluminum ring (30mm diameter, 10mm height) were used in the experiments. The aluminum ring was placed in a drilled hole (only slightly larger than the ring) in a horizontal wooden plate, and therefore, the surface of the beads was at the same level as the surrounding plane. Drops (d=4.2mm) of distilled water were created in a peristaltic pump and fell free from 1.5m. The final velocity of each drop was 4.98 m/s.

Three synchronized Phantom Miro M310 cameras were used to register the splash phenomenon (307 μs time interval, 1280 x 800 px resolution). The camera calibration process facilitated analysis of the trajectories of the splashed particles and determination of their velocities, ejection angles, and displacement distances.

The analysis of the recorded images was carried out using the Dantec Dynamics Studio software. The particles were tracked by the Volumetric 3D PTV module, and the trajectories were further analyzed by our script written in LabVIEW.

A hole (30mm diameter) was cut out of a piece of sticky paper, and the paper was placed concentrically over the ring. This allowed recording of all splashed particles while avoiding their rebounding or rolling from the plane. Following the impact, the beads were photographed using a Nikon D7100 camera, and images were analyzed using ImageJ software. The number of particles and the distance from the geometrical center of the drop impact were recorded. Measurements using the high-speed cameras and the sticky paper method were carried out in 16 repetitions.

Results

Table 1. *Characteristics of the particles splashed on various distances in the set of all splashed particles registered by a 3-D Volumetric PTV Module (Dantec Dynamics, Denmark)*

	Particle splashed on the distance (cm)						All detected particles
	< 2	2-4	4-6	6-8	8-10	10-12	
The share in the set of all detected particles (%)	25.5	60.8	10.1	2.9	0.5	0.1	100
The average speed of the splashed particles (m/s)	0.34	0.46	0.63	0.79	0.95	1.06	0.46
The average angle of splashed particles (˚)	58.9	45.7	42.2	39.1	39.9	43.7	48.5

The sticky paper method allowed each time to detect more particles than with high-speed cameras. In independent experiments, the total numbers of ejected glass beads ranged from 42 to 104, with an average of 71.5 and *SD* = 16.2. The average distance traveled by the ejected glass beads was equal to 2.5 cm with *SD* = 1.3.

Regarding the sticky paper method as a reference, the efficiency of identification with the high-speed cameras for the splash of glass beads was determined, which was estimated at 53%.

Conclusions

The high-speed cameras give a deeper insight into the nature of the trajectories of the ejected particles (e.g., by providing the parameters of these trajectories), as compared with the sticky paper method, they are characterized by a rather low efficiency of detection. This efficiency is about 53%. Nevertheless, the beads that were visible to the cameras seem to form a representative subset of the entire data.

References

Sochan A., Łagodowski A., Nieznaj E., Beczek M., Ryzak M., Mazur R., Bobrowski A., Bieganowski A. (2019). Splash of solid particles as a stochastic point process. Journal of Geophysical Research: Earth Surface, 124, 2475 2490. https://doi.org/10.1029/2018JF004993