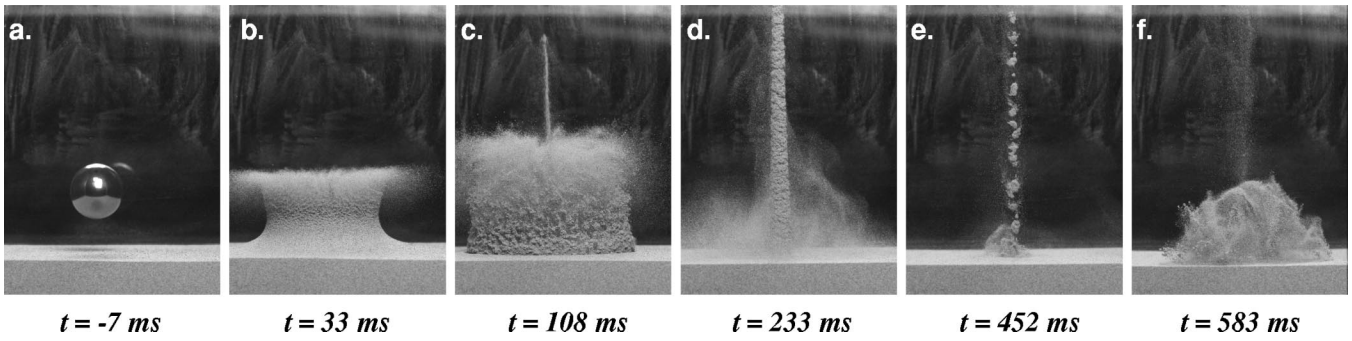

FIG. 1. Jet formation upon impact of a steel ball onto loose, very fine sand. A splash is formed (b), then a jet emerges [(c) and (d)]. After reaching its highest point, clusters are formed through inelastic collisions (e). A granular eruption concludes the series of events (f).

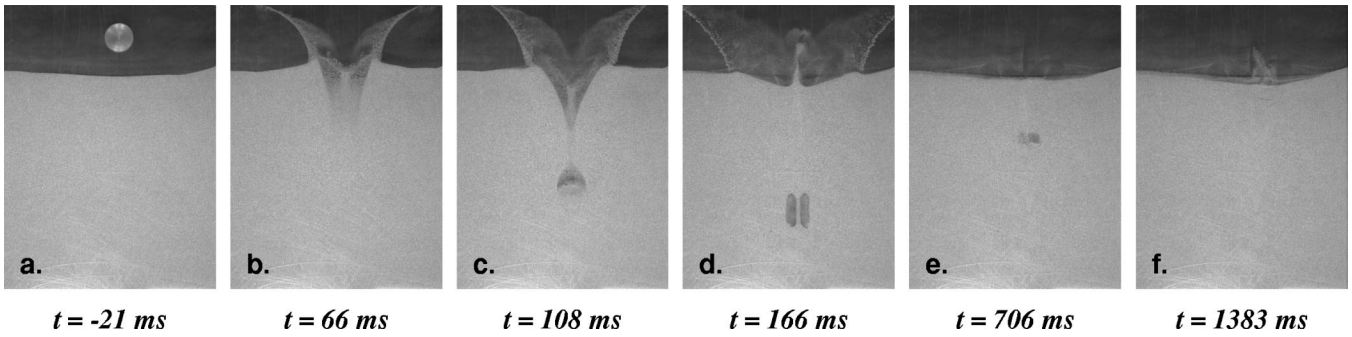

FIG. 2. The two-dimensional setup reveals the collapse of the void and the formation of the jet: The cylinder creates a void in the sand (b). Upon closure an air bubble is entrained (c) and two jets are produced: one upward, the other downward (d). The bubble slowly rises through the sand (e) and upon reaching the surface causes the granular eruption.

Granular Eruptions: Void Collapse and Jet Formation

Submitted by
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A steel ball dropped onto loose, very fine sand creates a jet.[1] Here, a container is filled with dry sand with an average grain size of 40 μm. Air is blown through the sand through a sintered bottom plate in order to make it loose and homogeneous. The air is slowly turned off before the experiments. A steel ball (25 mm diameter) is dropped into the sand [Fig. 1(a)] and the dynamics of the sand is recorded with a digital high-speed camera at 1000 frames per second.

The series of events is as follows:[2]

(1) **Splash:** The ball vanishes in the sand and a crown-like splash is created. Inhomogeneities develop in the crown, presumably due to the inelastic particle–particle interaction [Fig. 1(b)].
(2) **Void collapse and jet formation:** The ball creates a cylindrical void which collapses because of the sand pressure. When the accelerated sand grains from the sidewalls of the void collide on the axis of the void, a jet is formed [Figs. 1(c) and 1(d)]. In all our experiments the jet height exceeded the release height of the ball. When it comes down again the jet breaks up due to inelastic collisions of the sand particles, forming granular clusters [Fig. 1(e)].
(3) **Eruption:** An air bubble is formed in the void and slowly rises in the sand. When it hits the surface, it causes a granular eruption, resembling a volcano [Fig. 1(f)].

A two-dimensional setup reveals the jet-formation process. The ball was replaced by a cylinder which was dropped into a bed of sand between two transparent plates. The jet takes the form of a sheet making it less intense. The void formation [Fig. 2(b)] and collapse [Fig. 2(c)] are observed through the sidewalls. As the void closes an air bubble is entrained and it is seen [Fig. 2(d)] that, in fact, *two* jets are formed, one going upward and one going downward.

[1] S. T. Thoroddsen and A. Q. Shen, Phys. Fluids **13**, 4 (2001).
[2] See fdweb.tn.utwente.nl/granular/granular_eruptions.mpg for a video showing the series of events.